LMS/WEL/S04501

Weldon Spring Site Environmental Report for Calendar Year 2007

August 2008

Work Performed Under DOE Contract No. DE–AMO1–07LM00060
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Acronyms

AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
BTL	baseline tolerance limit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COD	Chemical Oxygen Demand
CWA	Clean Water Act
DA	Department of the Army
DNB	dinitrobenzene
DNT	dinitrotoluene
DO	dissolved oxygen
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
FFA	Federal Facility Agreement
ft	feet
ft/mi	feet per mile
GPS	global positioning system
GWOU	Groundwater Operable Unit
ha	hectare(s)
IC	Institutional Control
ICO	*in situ* chemical oxidation
IRA	Interim Response Action
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
LCRS	Leachate Collection and Removal System
LTS&M	Long-Term Surveillance and Maintenance
m	meter(s)
MCL	maximum contaminant level
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
mg/L	milligram(s) per liter
m/km	meter(s) per kilometer
MNA	monitored natural attenuation
MoDOT	Missouri Department of Transportation
MOU	Memorandum of Understanding
mrem	millirem
MSD	Metropolitan St. Louis Sewer District
msl	mean sea level
mSv	millisievert
MW	Monitoring Well
µg	microgram(s)
µg/L	microgram(s) per liter
N	nitrate
NB	nitrobenzene

ND	non-detect
NPL	National Priorities List
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
ORP	oxidation reduction potential
OU	Operable Unit
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi	picocurie(s)
pCi/L	picocurie(s) per liter
QROU	Quarry Residuals Operable Unit
Ra	radium
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RPD	relative percent difference
SC	specific conductivity
SDWA	Safe Drinking Water Act
SP	Spring
SWTP	Site Water Treatment Plant
TCE	trichloroethylene
TDS	total dissolved solids
Th	thorium
TNB	trinitrobenzene
TNT	trinitrotoluene
TOC	Total Organic Carbon
TRI	Toxic Release Inventory
USGS	United States Geological Survey
WSSRAP	Weldon Spring Site Remedial Action Project
yr	year

Executive Summary

This *Weldon Spring Site Environmental Report for Calendar Year 2007* has been prepared as required by U.S. Department of Energy (DOE) Order 231.1A, *Environmental, Safety, and Health Reporting*, to provide information about the environmental and health protection programs conducted at the Weldon Spring Site. The Weldon Spring Site is in southern St. Charles County, Missouri, approximately 48 kilometers (km) (30 miles) west of St. Louis. The Site consists of two main areas—the former Weldon Spring Chemical Plant and the Weldon Spring Quarry—located on Missouri State Route 94, southwest of U.S. Route 40/61.

The objectives of the *Site Environmental Report* are to present a summary of data from the environmental-monitoring program, to identify trends and characterize environmental conditions at the Site, and to confirm compliance with environmental- and health-protection standards and requirements. The report also presents the status of remedial activities, and the results of monitoring these activities in 2007, to assess their impacts on the public and environment. Since the Site has reached physical completion, the long-term surveillance and maintenance (LTS&M) activities have become the main focus of the project. Therefore, this report has been restructured and revised to reflect the reduction in physical activities and emphasizes LTS&M activities.

Compliance Summary

The Weldon Spring Site is listed on the National Priorities List and is governed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under CERCLA, the Weldon Spring Site has been subject to meeting or exceeding applicable or relevant and appropriate requirements of federal, state, and local laws. Primary regulations have included the Resource Conservation and Recovery Act and the Clean Water Act; because DOE is the lead agency for the Site, National Environmental Policy Act (NEPA) values are incorporated into CERCLA documents as outlined in the Secretarial Policy statement on NEPA. Many of these regulations are no longer applicable due to the reduction in physical activities and waste handling at the Site.

The Site has reached construction completion under CERCLA. The completion was documented in a Preliminary Closeout Report, which was issued by the U.S. Environmental Protection Agency (EPA) on August 22, 2005.

Because contamination remains at some of the areas of the Site at levels above those that allow unlimited use and unrestricted exposure, CERCLA requires that the remedial actions be reviewed at least every 5 years. These reviews are commonly called 5-year reviews. DOE issued the third 5-year review for the Site in September 2006. The next 5-year review will be completed in 2011.

A new Federal Facility Agreement (FFA) between EPA, DOE, and the Missouri Department of Natural Resources (MDNR) was signed by all parties; the final signature by EPA, on March 31, 2006. The focus of the new FFA is LTS&M activities.

Environmental Monitoring Summary

Historical water-quality and water-level data for existing wells can be found on the DOE Office of Legacy Management website: www.gjo.doe.gov/LM/. Photographs, maps, and physical features can also be viewed on this website.

Groundwater monitoring at the Chemical Plant was focused on the selected remedy of monitored natural attenuation (MNA) for the Groundwater Operable Unit. Total uranium, nitroaromatic compounds, trichloroethylene, and nitrate have been monitored at selected locations throughout the Chemical Plant area and off site. Sampling has targeted areas of highest impact in the shallow aquifer and migration pathways associated with paleochannels in the weathered unit of the Burlington-Keokuk Limestone.

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells, which are located within the areas of impact. These wells are monitored to verify that contaminant concentrations are declining as expected and that cleanup standards will be met within a reasonable timeframe. The different objectives are described in Section 3.1.1.3. The results for the MNA performance monitoring are included in Section 3.1.1.5.

Detection monitoring is performed to ensure that lateral and vertical migration remains confined to the current area of impact and that expected lateral downgradient migration within the paleochannels is minimal or nonexistent. Detection monitoring is performed by sampling the Objective 3 and 4 wells and Objective 5 springs and surface water locations. A summary of the results for the MNA detection monitoring is included in Section 3.1.1.6.

Groundwater monitoring at the Quarry was focused on the selected remedy of long-term groundwater monitoring for the Quarry Residuals Operable Unit. Total uranium, nitroaromatic compounds, and geochemical parameters have been monitored in the area of impact and in the Missouri River Alluvium. Groundwater is sampled under two programs that focus on the area of impact in the Quarry proper and north of the Femme Osage Slough and the Missouri River alluvium located south of the Femme Osage Slough. A summary of the results for the Quarry monitoring is included in Section 3.1.2.

Groundwater, spring, and leachate samples are collected as part of the detection monitoring program for the disposal cell. Under the monitoring program, signature parameter (barium, iron, manganese, and uranium) data from each location are compared to baseline tolerance limits to track general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if changes are occurring in the groundwater system. Leachate is sampled to verify its composition. A summary of the detection monitoring for the disposal cell is included in Section 3.1.3.

Surface water monitoring was conducted in the vicinity of the Chemical Plant and the Quarry to measure the effects of groundwater and surface water discharge on the quality of downstream surface water. A summary of the surface water monitoring results is included in Section 3.2.

LTS&M Activity Summary

The Weldon Spring Site Interpretive Center is part of DOE's LTS&M activities at the Site. Attendance for calendar year 2006 totaled 16,772.

The fourth annual public meeting required by the *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri Site* (LTS&M Plan) (DOE 2005a), was held on April 22, 2007. This meeting was held to discuss the 2006 annual inspection, which took place in December 2006. Also discussed were changes to the LTS&M Plan, a summary of environmental data, the MNA report, Institutional Control (IC) status, and the interpretive center/prairie activities.

The 2007 annual inspection took place on October 24 through 26, 2007. The main areas inspected were the disposal cell, the Quarry, the leachate collection and removal system, and monitoring wells. Areas where future ICs will be established were also inspected to verify that no groundwater or resource use that is incompatible with the necessary restrictions was occurring. The annual LTS&M public meeting was held on April 30, 2008.

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1.0 Introduction

This *Weldon Spring Site Environmental Report for Calendar Year 2007* summarizes the environmental-monitoring results obtained in 2007 and presents the status of federal and state compliance activities.

In 2007, environmental-monitoring activities were conducted to support remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Environmental Policy Act (NEPA), the Clean Water Act (CWA), and other applicable regulatory requirements. The monitoring program at the Weldon Spring Site has been designed to protect the public and to evaluate the effects on the environment, if any, from remediation activities.

The purposes of the *Weldon Spring Site Environmental Report for Calendar Year 2007* include:

- Providing general information on the Weldon Spring Site and the current status of remedial activities and long-term surveillance and maintenance (LTS&M) activities.
- Presenting summary data and interpretations for the environmental-monitoring program.
- Reporting compliance with federal, state, and local requirements and DOE standards.
- Providing dose estimates for public exposure to radiological compounds due to activities at the Weldon Spring Site.
- Summarizing trends and changes in contaminant concentrations to support remedial actions, ensure public safety, maintain surveillance monitoring requirements, and demonstrate the effectiveness of the remediation.

1.1 Site Description

The Weldon Spring Site is located in St. Charles County, Missouri, about 30 miles (48 kilometers [km]) west of St. Louis (Figure 1–1). The Site comprises two geographically distinct DOE-owned properties: the Weldon Spring Chemical Plant and Raffinate Pit Sites (Chemical Plant) and the Weldon Spring Quarry (Quarry). The Chemical Plant is located about 2 miles (2.3 km) southwest of the junction of Missouri State Route 94 and U.S. Highway 40/61. The Quarry is about 4 miles southwest of the Chemical Plant. Both sites are accessible from Missouri State Route 94.

During the early 1940s, the Department of the Army (DA) acquired 17,232 acres (6,974 hectares [ha]) of private land in St. Charles County for the construction of the Weldon Spring Ordnance Works facility. The former Ordnance Works Site has since been divided into several contiguous areas under different ownership as depicted on Figure 1–2. Current land use of the former Ordnance Works Site includes the Chemical Plant and Quarry, the U.S. Army Reserve Weldon Spring Training area, Missouri Department of Conservation (MDC) and Missouri Department of Natural Resources Division of State Parks, the Francis Howell High School, a Missouri Department of Transportation (MoDOT) maintenance facility, the St. Charles County water treatment facility and law enforcement training center, the village of Weldon Spring Heights, and a University of Missouri research park.

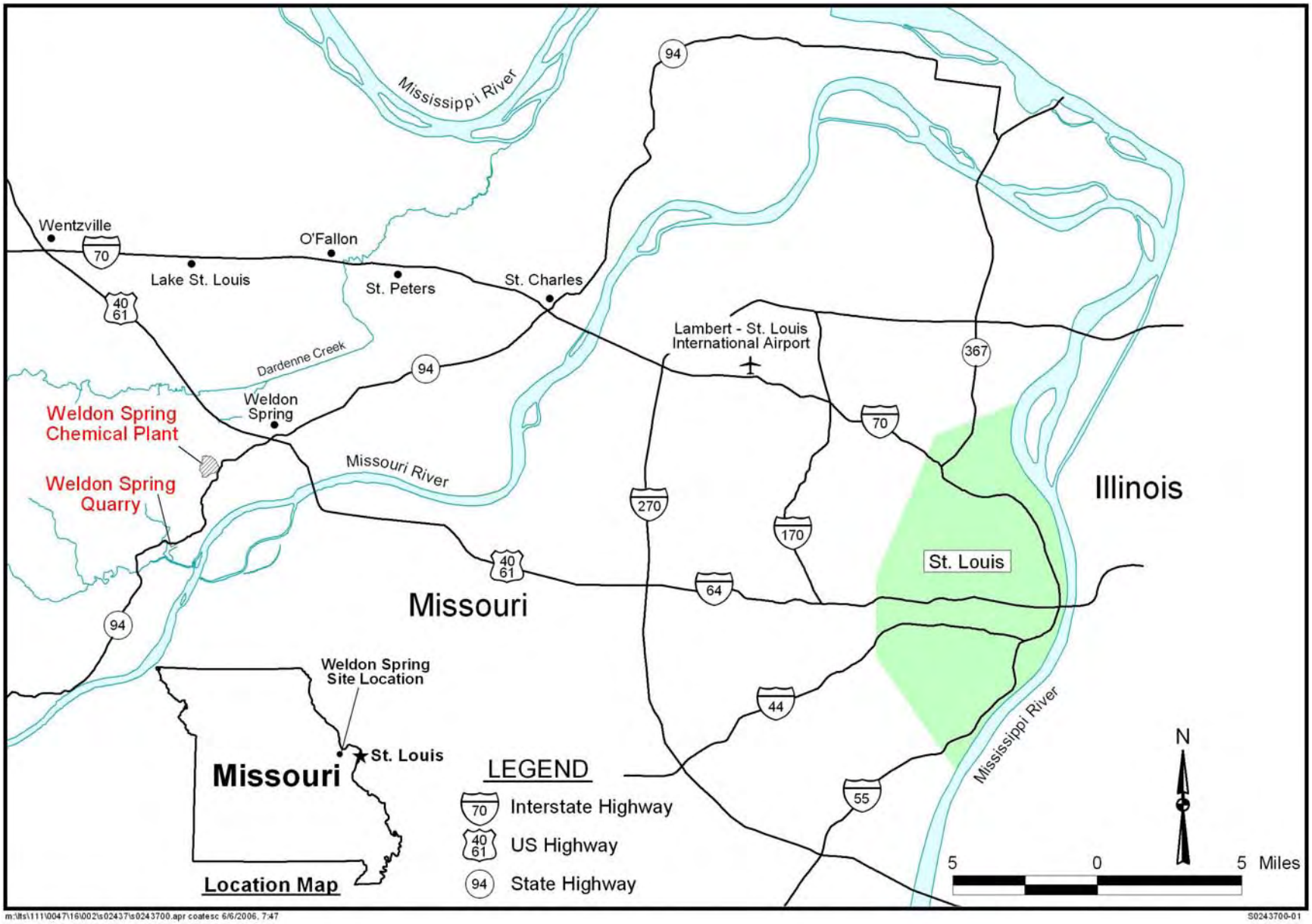

Figure 1–1. Location of the Weldon Spring, Missouri, Site

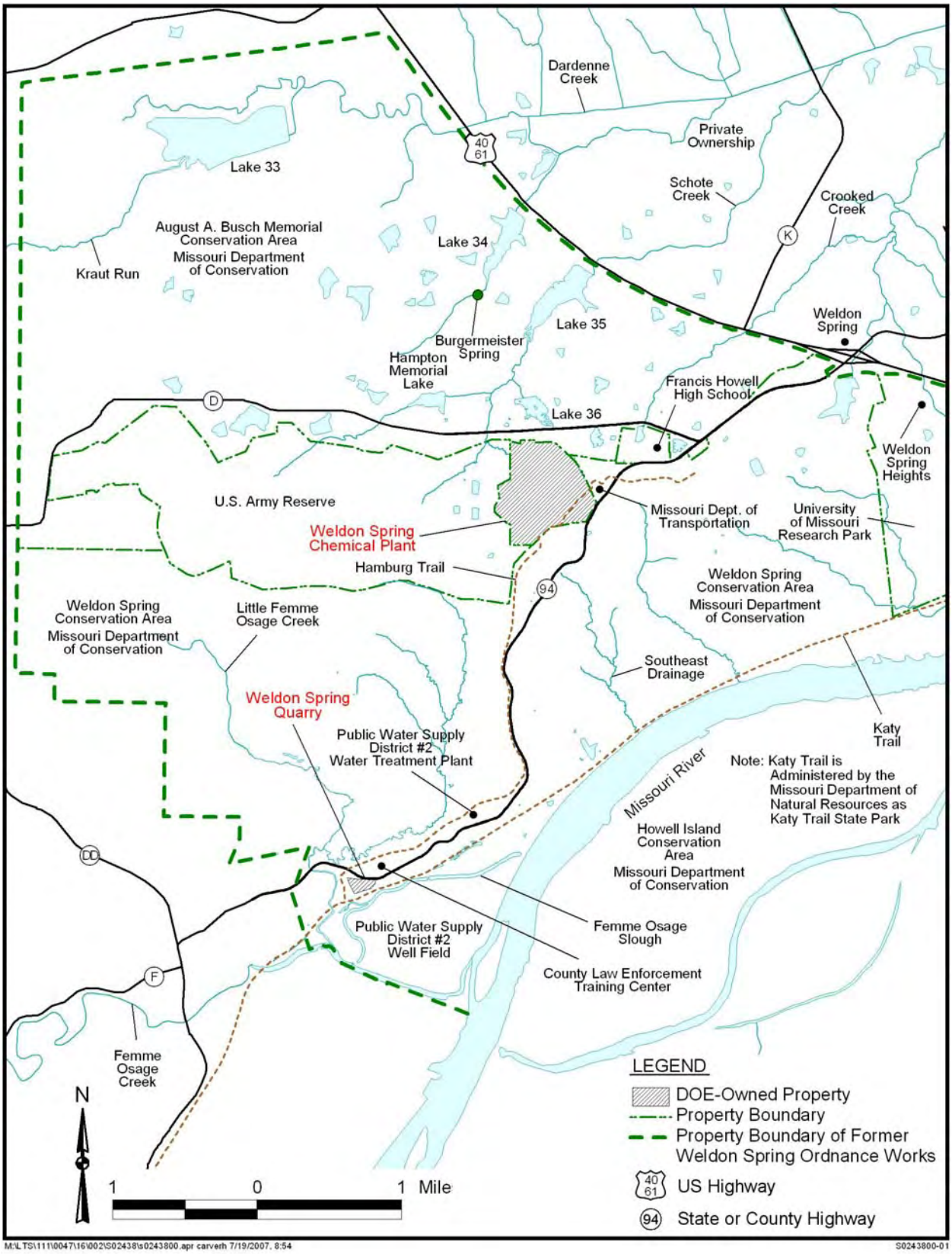

Figure 1–2. Vicinity Map of the Weldon Spring, Missouri, Site

The Chemical Plant and Quarry areas total 228.16 acres (92.33 ha). The Chemical Plant property is located on 219.50 acres (88.83 ha); the Quarry occupies 8.66 acres (3.50 ha).

1.2 Site History

1.2.1 Operations History

In 1941, the U.S. government acquired 17,232 acres (6,974 ha) of rural land in St. Charles County to establish the Weldon Spring Ordnance Works. In the process, the towns of Hamburg, Howell, and Toonerville and 576 citizens of the area were displaced (DA undated). From 1941 to 1945, the DA manufactured trinitrotoluene (TNT) and dinitrotoluene (DNT) at the Ordnance Works Site. Four TNT-production lines were situated on what was to be the Chemical Plant. These operations resulted in nitroaromatic contamination of soil, sediments, and some off-site springs.

Following a considerable amount of explosives decontamination of the facility by the Army and the Atlas Powder Company, 205 acres (83.0 ha) of the former Ordnance Works property were transferred to the U.S. Atomic Energy Commission (AEC) in 1956 for construction of the Weldon Spring Uranium Feed Materials Plant, now referred to as the Weldon Spring Chemical Plant. An additional 14.88 acres (6.02 ha) were transferred to AEC in 1964. The plant converted processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A small amount of thorium was also processed. Wastes generated during these operations were stored in four raffinate pits located on the Chemical Plant property. Uranium-processing operations resulted in the radiological contamination of the same locations previously contaminated by former Army operations.

The Quarry was mined for limestone aggregate used in the construction of the Ordnance Works. The Army also used the Quarry for burning wastes from explosives manufacturing and disposal of TNT-contaminated rubble during Ordnance Works operations. These activities resulted in the nitroaromatic contamination of the soil and groundwater at the Quarry.

In 1960, the Army transferred the Quarry to AEC, who used it from 1963 to 1969 as a disposal area for uranium and thorium residues (both drummed and uncontained) from the Chemical Plant and for disposal of contaminated building rubble, process equipment, and soils from demolition of a uranium-processing facility in St. Louis. Radiological contamination occurred in the same locations as the nitroaromatic contamination.

Uranium-processing operations ceased in 1966, and on December 31, 1967, AEC returned the facility to the Army for use as a defoliant-production plant. In preparation for the defoliant process, the Army removed equipment and materials from some of the buildings and disposed of them principally in Raffinate Pit 4. The defoliant project was canceled before any process equipment was installed, and the Army transferred 50.65 acres (20.50 ha) of land encompassing the raffinate pits back to AEC while retaining the Chemical Plant. AEC, and subsequently DOE, managed the Site, including the Army-owned Chemical Plant, under caretaker status from 1968 through 1985. Caretaker activities included Site security oversight, fence maintenance, grass cutting, and other incidental maintenance. In 1984, the Army repaired several of the buildings at the Chemical Plant; decontaminated some of the floors, walls, and ceilings; and isolated some equipment. In 1985, the Army transferred full custody of the Chemical Plant to DOE, at which

time, DOE designated the control and decontamination of the Chemical Plant, raffinate pits, and Quarry as a major project.

1.2.2 Remedial Action History

The U.S. Environmental Protection Agency (EPA) placed the Quarry and Chemical Plant areas on the National Priorities List (NPL) in 1987 and 1989, respectively. Initial remedial activities at the Chemical Plant, a series of Interim Response Actions (IRAs) authorized through the use of Engineering Evaluation/Cost Analysis (EE/CA) reports, included:

- The removal of electrical transformers, electrical poles and lines, and overhead piping and asbestos that presented an immediate threat to workers and the environment.
- The construction of an isolation dike to divert runoff around the Ash Pond area to reduce the concentration of contaminants going off site in surface water.
- A detailed characterization of on-site debris, the separation of radiological and nonradiological debris, and the transport of materials to designated staging areas for interim storage.
- The dismantling of 44 Chemical Plant buildings under four separate IRAs.
- The treatment of contaminated water at the Chemical Plant and the Quarry.

Remediation of the Weldon Spring Site was administratively divided into four operable units (OUs): the Quarry Bulk Waste OU, the Quarry Residuals OU (QROU), the Chemical Plant OU, and the Groundwater OU (GWOU). The Southeast Drainage was remediated as a separate action through an EE/CA report (DOE 1996). The selected remedies are described in the following sections.

1.2.2.1 Chemical Plant OU

In the *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993), DOE established the remedy for controlling contaminant sources at the Chemical Plant (except groundwater) and disposing of contaminated materials in an on-site disposal cell.

The selected remedy included:

- The removal of contaminated soils, sludge, and sediment.
- The treatment of wastes, as appropriate, by chemical stabilization/solidification.
- The disposal of wastes removed from the Chemical Plant and stored Quarry bulk wastes in an engineered on-site disposal facility.

The remedy included the remediation of 17 off-site vicinity properties affected by Chemical Plant operations. The vicinity properties were remediated in accordance with Chemical Plant Record of Decision (ROD) cleanup criteria.

The *Chemical Plant Operable Unit Remedial Action Report* (DOE 2004a) was finalized in January 2004.

1.2.2.2 Quarry Bulk Waste OU

DOE implemented remedial activities for the Quarry Bulk Waste OU set forth in the *Record of Decision for Management of Bulk Wastes at the Weldon Spring Quarry* (DOE 1990b).

The selected remedy included:

- The excavation and removal of bulk waste (i.e., structural debris, drummed and unconfined waste, process equipment, sludge, soil).
- The transportation of waste along a dedicated haul road to a temporary storage area located at the Chemical Plant.
- The staging of bulk wastes at the temporary storage area.

1.2.2.3 Quarry Residuals OU

The QROU remedy was described in the *Record of Decision for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1998b). The QROU addressed residual soil contamination in the Quarry proper, surface water and sediments in the Femme Osage Slough and nearby creeks, and contaminated groundwater.

The selected remedy included:

- Long-term monitoring and institutional controls (ICs) to prevent exposure to contaminated groundwater north of the Femme Osage Slough.
- Long-term monitoring and ICs to protect the quality of the public water supply in the Missouri River alluvium and the implementation of a well-field contingency plan.
- Confirming the model assumptions regarding the extraction of contaminated groundwater and establishing controls to protect naturally occurring attenuation processes.
- Restoring the Quarry and establishing ICs.

The *Quarry Residual Operable Unit Remedial Action Report* (DOE 2003b) was finalized in January 2004.

1.2.2.4 Groundwater OU

DOE implemented an interim ROD, which was approved on September 29, 2000, to investigate the practicability of remediating trichloroethene (TCE) contamination in Chemical Plant groundwater, using *in situ* chemical oxidation (ICO) (DOE 2000b). It was determined, based on extensive monitoring, that the ICO did not perform adequately under field conditions; therefore, the remediation of TCE was reevaluated with the remaining contaminants of concern.

DOE issued a final ROD (DOE 2004f) in January 2004, which was signed by EPA in February 2004. The GWOU ROD selected a remedy of monitored natural attenuation (MNA) with ICs to limit groundwater use during the period of remediation. MNA involves the collection of monitoring data to verify the effectiveness of naturally occurring processes to reduce contaminant concentrations over time. The ROD establishes remedial goals and performance standards for MNA. Activities regarding the GWOU are further discussed in Section 3.1.

1.2.2.5 Southeast Drainage

Remedial action for the Southeast Drainage was addressed as a separate action under CERCLA. The *Engineering Evaluation/Cost Analysis for the Proposed Removal Action at the Southeast Drainage near the Weldon Spring Site, Weldon Spring, Missouri* (DOE 1996) was prepared in August 1996 to evaluate the human and ecological health risks within the drainage. The EE/CA recommended that selected sediment in accessible areas of the drainage should be removed with track-mounted equipment and transported by off-road haul trucks to the Chemical Plant. The excavated materials would be stored temporarily at an on-site storage area until final disposal in the disposal cell. Soil removal occurred in two phases: 1997 to 1998, and in 1999. Post-remediation soil sampling was conducted. More details are included in the *Southeast Drainage Closeout Report Vicinity Properties DA-4 and MDC-7* (DOE 1999b).

1.3 Final Site Conditions

Contamination remains at the Weldon Spring Site at the following locations:

- An on-site disposal cell contains approximately 1.48 million cubic yards of contaminated material.
- Residual groundwater contamination remains in the shallow aquifer beneath the Chemical Plant, at the Quarry, and at some surrounding areas.
- Several springs near the Chemical Plant discharge contaminated groundwater.
- Residual soil and sediment contamination remain in the Southeast Drainage.
- Contamination remains at two culvert locations along Missouri State Route 94 and Highway D.
- Residual soil contamination remains at inaccessible locations within the Quarry.

1.4 Geology and Hydrogeology

Due to lithologic differences, including geologic features that influence groundwater flow, and the geographical separation of the Chemical Plant and Quarry areas, separate groundwater monitoring programs have been established for the two sites. Generalized geologic and hydrologic descriptions of the two sites are found in this section. A generalized stratigraphic column for reference is provided on Figure 1–3. Hydrogeologic descriptions of lithologies monitored for each program are discussed in Sections 3.1.1.1 and 3.1.2.1. The appropriate cleanup standards for groundwater in each area of the Weldon Spring Site are summarized in Section 2.1.1.5.

The Weldon Spring Site is situated near the boundary between the Central Lowland and the Ozark Plateau physiographic provinces. This boundary nearly coincides with the southern edge of Pleistocene glaciation that covered the northern half of Missouri over 10,000 years ago (Kleeschulte et al. 1986).

System	Series	Stratigraphic Unit	Typical Thickness (feet)[a]	Physical Characteristics	Hydrostratigraphic Unit
Quaternary	Holocene	Alluvium	0–120	Gravelly, silty loam	Alluvial aquifer
	Pleistocene	Loess and glacial drift[b]	10–60	Silty clay, gravelly clay, silty loam, or loam over residuum from weathered bedrock	Locally a leaky confining unit[c]
Mississippian	Meramecian	Salem Formation[c]	0–15	Limestone, limey dolomite, finely to coarsely crystalline, massively bedded, and thin bedded shale	
		Warsaw Formation[c]	0–80	Shale and thin to medium bedded finely crystalline limestone with interbedded chert	
	Osagean	Burlington-Keokuk Limestone	100–200	Cherty limestone, very fine to very coarsely crystalline, fossiliferous, thickly bedded to massive	Shallow aquifer system
		Fern Glen Limestone	45–70	Cherty limestone, dolomitic in part, very fine to very coarsely crystalline, medium to thickly bedded	
	Kinderhookian	Chouteau Limestone	20–50	Dolomitic argillaceous limestone, finely crystalline, thin to medium bedded	Upper leaky confining unit
Devonian	Upper	Sulphur Springs Group Bushberg Sandstone[d]	40–55	Quartz arenite, fine to medium grained, friable	
		Lower part of Sulphur Springs Group undifferentiated		Calcareous siltstone, sandstone, oolitic limestone, and hard carbonaceous shale	
Ordovician	Cincinnatian	Maquoketa Shale[e]	0–30	Calcareous to dolomitic silty shale and mudstone, thinly laminated to massive	
	Champlainian	Kimmswick Limestone	70–100	Limestone, coarsely crystalline, medium to thickly bedded, fossiliferous and cherty near base	Middle aquifer system
		Decorah Group	30–60	Shale with thin interbeds of very finely crystalline limestone	Lower confining unit
		Plattin Limestone	100–130	Dolomitic limestone, very finely crystalline, fossiliferous, thinly bedded	
		Joachim Dolomite	80–105	Interbedded very finely crystalline, thinly bedded dolomite, limestone, and shale; sandy at base	
		St. Peter Sandstone	120–150	Quartz arenite, fine to medium grained, massive	Deep aquifer system
	Canadian	Powell Dolomite	50–60	Sandy dolomite, medium to finely crystalline, minor chert and shale	
		Cotter Dolomite	200–250	Argillaceous, cherty dolomite, fine to medium crystalline, interbedded with shale	
		Jefferson City Dolomite	160–180	Dolomite, fine to medium crystalline	
		Roubidoux Formation	150–170	Dolomitic sandstone	
		Gasconade Dolomite	250	Cherty dolomite and arenaceous dolomite (Gunter Member)	
Cambrian	Upper	Eminence Dolomite	200	Dolomite, medium to coarsely crystalline, medium bedded to massive	
		Potosi Dolomite	100	Dolomite, fine to medium crystalline, thickly bedded to massive; drusy quartz common	

[a]Thickness estimates vary depending on data source.
[b]Glacial drift unit includes the Ferrelview Formation and is saturated in the northern portion of the Ordnance Works where this unit behaves locally as a leaky confining unit.
[c]The Warsaw and Salem Formations are not present in the Weldon Spring area.
[d]The Sulphur Springs Group also includes the Bachelor Sandstone and the Glen Park Limestone.
[e]The Maquoketa Shale is not present in the Weldon Spring Area.

Figure 1–3. Generalized Stratigraphy and Hydrostratigraphy of the Weldon Spring, Missouri, Site

The uppermost bedrock units underlying the Weldon Spring Chemical Plant are the Mississippian Burlington and Keokuk Limestone. Overlying the bedrock are unlithified units consisting of fill, topsoil, loess, glacial till, and limestone residuum of thicknesses ranging from a few feet to several tens of feet.

There are three bedrock aquifers underlying St. Charles County. The shallow aquifer consists of Mississippian Limestones, and the middle aquifer consists of Ordovician Kimmswick Limestone. The deep aquifer includes formations from the top of the Ordovician St. Peter Sandstone to the base of the Cambrian Potosi Dolomite. Alluvial aquifers of Quaternary age are present near the Missouri and Mississippi rivers.

The Weldon Spring Quarry is located in low limestone hills near the northern bank of the Missouri River. The mid-Ordovician bedrock of the Quarry area includes, in descending order, Kimmswick Limestone, Decorah Formation, and Plattin Limestone. These formations are predominantly limestone and dolomite. Near the Quarry, the carbonate rocks dip to the northeast at a gradient of 11 meters per kilometer (m/km) to 15 m/km (58 feet [ft] per mile [ft/mi] to 79 ft/mi) (DOE 1990a). Massive Quaternary deposits of Missouri River alluvium cover the bedrock to the south and east of the Quarry.

1.5 Surface Water System and Use

The Chemical Plant and Raffinate Pits areas are on the Missouri−Mississippi River surface drainage divide. Elevations on the Site range from approximately 185 meters (m) (608 ft) above mean sea level (msl) near the northern edge of the Site to 203 m (665 ft) above msl near the southern edge. (The cell is not included in these elevation measurements.) The natural topography of the Site is gently undulating in the upland areas, typical of the Central Lowlands physiographic province. South of the Site, the topography changes to the narrow ridges and valleys and short, steep streams common to the Ozark Plateau physiographic province (Kleeschulte et al. 1986).

No natural drainage channels traverse the Site. Drainage from the southeastern portion of the Site generally flows southward to a tributary referred to as the Southeast Drainage (or 5300 Drainageway, based on the Site's nomenclature) that flows to the Missouri River.

The northern and western portions of the Chemical Plant Site drain to tributaries of the Busch Lakes and Schote Creek, which in turn enter Dardenne Creek, which ultimately drains to the Mississippi River. The manmade lakes in the August A. Busch Memorial Conservation Area are used for public fishing and boating. No swimming is allowed in the conservation area, although some may occur. No water from the lakes or creeks is used for irrigation or for public drinking-water supplies.

Before the remediation of the Chemical Plant and Raffinate Pits areas began, there were six surface water bodies on the Site: the four raffinate pits, Frog Pond, and Ash Pond. The water in the raffinate pits was treated prior to release, and the pits were remediated and confirmed clean. Frog Pond and Ash Pond were flow-through ponds that were monitored prior to being remediated and confirmed clean. Throughout the project, retention basins and sedimentation basins were constructed and used to manage potentially contaminated surface water. During

2001, the four sedimentation basins that remained were remediated, and the entire Site was brought to final grade and seeded with temporary vegetation. Final seeding was conducted during 2002.

The Weldon Spring Quarry is situated on a bluff of the Missouri River Valley about 1.6 km (1 mile) northwest of the Missouri River at approximately River Mile 49. Because of the topography of the area, no direct surface water entered or exited the Quarry before it was remediated. A 0.07 ha (0.2-acre) pond within the Quarry proper acted as a sump that accumulated direct rainfall within the Quarry. Past dewatering activities in the Quarry suggested that the sump interacted directly with the local groundwater. All water pumped from the Quarry before remediation was treated before it was released. Bulk waste removal, which included the removal of some sediment from the sump area, was completed during 1995. The Quarry was backfilled, graded, and seeded during 2002.

The Femme Osage Slough, located approximately 213 m (700 ft) south of the Quarry, is a 2.4 km (1.5 mile) section of the original Femme Osage Creek and Little Femme Osage Creek. The University of Missouri dammed portions of the creeks between 1960 and 1963 during the construction of a levee system around the university's experimental farms (DOE 1990a). The slough is essentially landlocked and is currently used for recreational fishing. The slough is not used for drinking water or irrigation.

1.6 Ecology

The Weldon Spring Site is surrounded primarily by State conservation areas that include the 2,828-ha (6,988-acre) Busch Conservation Area to the north, the 2,977-ha (7,356 acres) Weldon Spring Conservation Area to the east and south, and the Howell Island Conservation Area, an island in the Missouri River which covers 1,031 ha (2,548 acres) (Figure 1–2).

The wildlife areas are managed for multiple uses, including timber, fish and wildlife habitat, and recreation. Fishing constitutes a relatively large portion of the recreational use. Seventeen percent of the area consists of open fields that are leased to sharecroppers for agricultural production. In these areas, a percentage of the crop is left for wildlife use. The main agricultural products are corn, soybeans, milo, winter wheat, and legumes (DOE 1992b). The Busch and Weldon Spring Conservation areas are open year-round, and the number of annual visits to both areas totals about 1,200,000.

The Quarry is surrounded by the Weldon Spring Conservation Area, which consists primarily of forest with some old field habitat. Prior to bulk waste removal, the Quarry floor consisted of old-field habitat containing a variety of grasses, herbs, and scattered wooded areas. When bulk waste removal began, this habitat was disturbed. The rim and upper portions of the Quarry still consist primarily of slope and upland forest, including cottonwood, sycamore, and oak (DOE 1990a).

1.7 Climate

The climate in the Weldon Spring area is continental, with warm to hot summers and moderately cold winters. Air masses that are alternately warm and cold, and wet and dry converge and pass through the area, causing frequent changes in the weather. Although winters are generally cold and summers are generally hot, prolonged periods of very cold or very warm to hot weather are

unusual. Occasional mild periods with temperatures above freezing occur almost every winter, and cool weather interrupts periods of heat and humidity in the summer (Ruffner and Bair 1987).

On its website, the National Oceanic and Atmospheric Administration has published information based on an analysis of long-term meteorological records for the St. Louis area. The page, titled *The Climatology of the St. Louis Area*, states the following:

> St. Louis is located at the confluence of the Mississippi and Missouri Rivers, and near the geographical center of the US. Its position in the middle latitudes allows the area to be affected by warm moist air that originates in the Gulf of Mexico, as well as cold air masses that originate in Canada. The alternate invasion of these air masses produces a wide variety of weather conditions, and allows the region to enjoy a true four-season climate.
>
> During the summer months, air originating from the Gulf of Mexico tends to dominate the area, producing warm and humid conditions. Since 1870, records indicate that temperature of 90 degrees or higher occur on about 35-40 days per year. Extremely hot days (100 degrees or more) are expected on no more than 5 days per year.
>
> Winters are brisk and stimulating, but prolonged periods of extremely cold weather are rare. Records show that temperatures drop to zero or below an average of 2 or 3 days per year, and temperatures as cold as 32 degrees or lower occur less than 25 days in most years. Snowfall has averaged a little over 18 inches per winter season, and snowfall of an inch or less is received on 5 to 10 days in most years.
>
> Normal annual precipitation for the St. Louis is a little less than 34 inches. The three winter months are the driest, with an average total of about 6 inches of precipitation. The spring months of March through May are normally the wettest with normal total rainfall of just under 10.5 inches. It is not unusual to have extended dry periods of one to two weeks during the growing season.
>
> Thunderstorms normally occur on between 40 and 50 days per year. During any year, there are usually a few of these thunderstorms that are severe, and produce large hail and damaging winds.

The on-site meteorological station was dismantled in May 2002 to facilitate final Site restoration activities. The precipitation and temperature results in Table 1–1 are from the National Weather Service. Precipitation and average temperature were all within historical ranges for the St. Louis area.

Table 1–1. Monthly Meteorological Monitoring Results for 2007

Month	Total Precipitation (cm)[a]	Average Temperature (°C)
January	3.11	1.17
February	1.98	1.50
March	2.80	12.00
April	3.18	12.17
May	4.26	21.61
June	2.88	24.67
July	3.11	25.78
August	1.57	29.11
September	1.71	23.33
October	1.97	17.28
November	1.25	8.06
December	2.75	1.94

[a]cm = centimeters

1.8 Land Use and Demography

The 2005 census estimated the population of St. Charles County to be about 329,940. This represents a 16.2 percent increase from the 2000 census and about a 30 percent increase over the past 10 years. The three largest communities in St. Charles County are O'Fallon (population: 67,009), St. Charles (population: 61,411), and St. Peters (population: 53, 907) (Figure 1–1). The two communities closest to the Site are Weldon Spring and Weldon Spring Heights, about 3.2 km (2 miles) to the northeast. The combined population of these two communities is about 5,000. No private residences exist between Weldon Spring Heights and the Site. Urban areas occupy about 6 percent of county land, and nonurban areas occupy 90 percent; the remaining 4 percent is dedicated to transportation and water uses.

Francis Howell High School is about 1 km (0.6 mile) northeast of the Site along Missouri State Route 94 (Figure 1–2). The school employs approximately 150 faculty and staff, and about 1,760 students attend school there. In addition, approximately 50 full-time employees work at the high school annex, and about 50 bus drivers park their school buses in the adjacent parking lot.

The MoDOT Weldon Spring maintenance facility, located adjacent to the north side of the Chemical Plant, employs about 10 workers. The Army Reserve Training Area is to the west of the Chemical Plant and in the past was periodically visited by DA trainees and law enforcement personnel. Presently, there are about 40 full-time personnel working on military equipment at the DA site. During 2005, the training site had 18,000 man-days of usage by all branches of the military and law enforcement. About 300 ha (741 acres) of land east and southeast of the high school is owned by the University of Missouri. The northern third of this land is being developed into a high-technology research park. The conservation areas adjacent to the Chemical Plant are operated by MDC and employ about 50 people.

2.0 Compliance Summary

2.1 Compliance Status for 2007

The Weldon Spring Site is listed on the NPL; therefore, it has been—and is—governed by the CERCLA process. Under CERCLA, the Weldon Spring Site Remedial Action Project (WSSRAP) was subject to meeting or exceeding the applicable or relevant and appropriate requirement (ARARs) of federal, state, and local laws and statutes, such as the Resource Conservation and Recovery Act (RCRA), the CWA, the Clean Air Act, the National Historic Preservation Act, the Safe Drinking Water Act (SDWA), the Endangered Species Act, and Missouri State regulations. Because DOE is the lead agency for the Site, NEPA values must be incorporated. The requirements of DOE orders must also be met. Section 2.1.1 is a summary of compliance with applicable federal and state regulations, Section 2.1.2 is a summary of compliance with major DOE orders, and Section 2.1.3 is a discussion of compliance agreements and permits. The physical completion of the project has reduced—or, in some cases, eliminated—the applicability of certain ARARs.

2.1.1 Federal and State Regulatory Compliance

2.1.1.1 Comprehensive Environmental Response, Compensation, and Liability Act

The Weldon Spring Site has integrated the procedural and documentation requirements of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, and NEPA. The remedial actions conducted under CERCLA are discussed in Section 1.2.2.

The Site has reached construction completion under CERCLA. The completion was documented in a Preliminary Closeout Report, which EPA issued on August 22, 2005.

Because some areas of the Site are still contaminated beyond levels that would allow unlimited use and unrestricted exposure, CERCLA requires that the remedial actions be reviewed at least every 5 years. These reviews are commonly called 5-year reviews. DOE completed the third 5-year-review report for the Site in September 2006.

2.1.1.2 Resource Conservation and Recovery Act

Hazardous wastes at the Weldon Spring Site have been managed as required by RCRA as substantive ARARs. This has included the characterization, consolidation, inventory, storage, treatment, disposal, and transportation of hazardous wastes that remained on site after the closure of the Weldon Spring Uranium Feed Materials Plant and wastes that were generated during remedial activities.

An RCRA treatment, storage, and disposal permit was not required at the Site because the remediation has been performed in accordance with decisions reached under CERCLA. Section 121(e) of CERCLA states that no federal, state, or local permit shall be required for the portion of any removal or remedial action conducted entirely on site.

The Weldon Spring Site no longer generates any hazardous waste and has deactivated its generator identification number.

The disposal cell contents are not regulated under RCRA, but RCRA post-closure disposal cell monitoring and maintenance requirements are ARARs. The RCRA groundwater protection standard (40 *Code of Federal Regulations* [CFR] 264 Subpart F) sets forth the general groundwater monitoring requirements for the disposal cell. Generally, the disposal cell groundwater monitoring program must provide representative samples of background groundwater quality, as well as groundwater passing the point of compliance. For a more complete description, see the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan* (DOE 2004b) which was developed to address these requirements. Additional post-closure requirements for the cell are identified in 40 CFR 264 Subpart N and include action leakage rate and leachate collection and removal requirements. These requirements are addressed in the *Long-Term Surveillance and Maintenance Plan for the U.S. Department of Energy Weldon Spring, Missouri Site* (LTS&M Plan) (DOE 2005a). Subpart N also includes requirements to maintain the integrity of the final cover, including making repairs as necessary.

2.1.1.3 Clean Water Act

Effluents discharged to waters of the United States are regulated under the CWA through regulations promulgated and implemented by the State of Missouri. The federal government has granted regulatory authority for implementation of CWA provisions to states with regulatory programs that are at least as stringent as the federal program.

Compliance with the CWA at the Site has included meeting parameter limits and permit conditions specified in the National Pollutant Discharge Elimination System (NPDES) permits. Under these permits, both effluent and erosion-control monitoring have been performed. The majority of these remaining permits were terminated in 2003, and the Site has no off-site discharges at this time. See Section 2.1.3 for additional discussion of the remaining permit.

2.1.1.4 Safe Drinking Water Act

SDWA regulations are not applicable because maximum contaminant levels (MCLs) apply only to drinking water at the tap, not in groundwater. However, under the National Contingency Plan, MCLs are relevant and appropriate to groundwater that is a potential drinking-water source. The principal ARARs for the impacted groundwater at the Chemical Plant are the MCLs and Missouri water-quality standards, which were established in the GWOU ROD and are shown in Table 2–1.

Long-term groundwater monitoring for the QROU consists of two separate programs. Groundwater monitoring is necessary to continue to ensure that uranium-contaminated groundwater has a negligible potential to affect the well field that was formerly owned by St. Charles County and is now owned by Public Water District #2. The first program details the monitoring of uranium and 2,4-DNT south of the slough to ensure that levels remain protective of human health and the environment. The second program consists of monitoring groundwater contaminant levels within the area north of the slough until they attain a predetermined target level indicating negligible potential to affect groundwater south of the slough.

Table 2–1. Federal and State Water-Quality Standards for the Chemical Plant GWOU

Constituent	Standard	Citation
Nitrate (as N)	10 mg/L	40 CFR 141.62
Total Uranium	20 pCi/L	40 CFR 141
1,3-DNB	1.0 µg/L	10 CSR 20-7[a]
2,4-DNT	0.11 µg/L	10 CSR 20-7[a]
NB	17 µg/L	10 CSR 10-7[a]
TCE	5 µg/L	40 CFR 141.61
2,6-DNT	1.3 µg/L	Risk Based[b]
2,4,6-TNT	2.8 µg/L	Risk Based[c]

[a]Missouri Groundwater Quality Standard.
[b]Risk-based concentration equivalent to 10^{-5} for a resident scenario.
[c]Risk-based concentration equivalent to 10^{-6} for a resident scenario.
Key: DNB = dinitrobenzene; NB = nitrobenzene; DNT = dinitrotoluene; mg/L = milligram(s) per liter; pCi/L = picocurie per liter; µg/L = microgram(s) per liter

The objective for monitoring groundwater south of the slough is to verify that the groundwater is not impacted. Uranium concentrations south of the slough and in the area of production wells at the well field remain within the observed natural variation within the aquifer; therefore, the MCL for uranium of 20 picocuries per liter (pCi/L) has been established as a trigger level only in this area. If concentrations in groundwater south of the slough exceed the MCL of 20 pCi/L, DOE will evaluate risk and take appropriate action.

Under current conditions, groundwater north of the slough poses no imminent risk to human health from water obtained from the well field. A target level of 300 pCi/L for uranium (10 percent of the 1999 maximum) was established to represent a significant reduction in the contaminant levels north of the slough. The target level for 2,4-DNT has been set at 0.11 micrograms per liter (µg/L), the Missouri Water Quality standard.

2.1.1.5 Emergency Planning and Community Right-to-Know Act

The Site no longer stores large quantities of chemicals and none above a threshold level; therefore, the Site is not required to submit a 2007 *Emergency Planning and Community Right-to-Know Act* Tier II report.

The Toxic Release Inventory (TRI) report for 2007 is due on July 1, 2008. Based on the chemical usage in 2007, the Weldon Spring Site is not required to submit a TRI report.

2.1.2 DOE Order Compliance

2.1.2.1 DOE Order 5400.5, Radiation Protection of the Public and the Environment

DOE Order 5400.5 establishes primary standards and requirements for DOE operations to protect members of the public and the environment against undue risk from radiation. DOE operates its facilities and conducts its activities so that radiation exposures to members of the public are maintained within established limits.

The estimated total effective dose equivalent to the hypothetical maximally exposed individual was due to consumption of water from Burgermeister Spring. This dose was calculated to be

0.17 millirem (mrem), which is well below the 100 mrem (1 millisievert [mSv]) guideline for all potential exposure pathways.

2.1.2.2 DOE Order 231.1A, Environmental, Safety, and Health Reporting

DOE Order 231.1A and DOE Manual 231.1-1A ensures the collection and reporting of information on environment, safety, and health that is required by law or regulation. This site environmental report fulfills the requirement of the order to summarize the environmental data annually. These directives also include requirements for occurrence reporting. There were no occurrences as defined by these directives at the Site during 2006.

2.1.3 Permit and Agreement Compliance

2.1.3.1 NPDES Permits

The Weldon Spring Site has no off-site discharges at this time and has one NPDES permit (MO-0107701). The permit only covers the former Site Water Treatment Plant (SWTP) discharge line. The SWTP discharge line will only be used if the Site ever operates Train 3 at the leachate collection and removal system (LCRS) as a contingency to current disposal methods (see Section 2.1.3.3). This permit's expiration date was in July 2005. DOE submitted a renewal application to the Missouri Department of Natural Resources (MDNR) in January 2005, and the MDNR issued a new permit to the Site in April 2008.

2.1.3.2 Federal Facility Agreement

A Federal Facility Agreement (FFA) was signed by EPA and DOE in 1986, and it was amended in 1992. The main purpose of the FFA is to establish a procedural framework and schedule for developing, implementing, and monitoring appropriate response actions at the Site in accordance with CERCLA. An FFA report was issued to EPA and MDNR each quarter. It documented compliance with the FFA and reported on activities at the Site.

A new FFA between EPA, DOE, and MDNR was signed by all parties, with the final signature by EPA on March 31, 2006. The focus of the new FFA is LTS&M activities. A quarterly report is no longer required by the new version of the FFA.

2.1.3.3 Metropolitan St. Louis Sewer District (MSD) Agreement

The Weldon Spring Site has approval from the MSD to haul disposal cell leachate and purge water to their Bissell Point Plant. The DOE received notification in April 2004 that the leachate must meet the radiological drinking-water standard of 30 µg/L (20 pCi/L) prior to acceptance. The disposal cell leachate was very close to this limit in 2004; therefore, DOE exercised a pretreatment contingency process and began treating the leachate through a system of cartridge filters and ion-exchange media that is selective for uranium. The leachate was sampled after treatment and found to be significantly below the 30 µg/L limit for uranium. The pretreated levels continued to be close to the 30 µg/L limit during 2006, so the leachate continued to be treated by the same process with the same results (that is, the levels continued to be significantly lower than the 30-µg/L limit). On November 3, 2006, DOE received a 5-year extension letter from MSD, extending the agreement to December 21, 2011. The leachate is discussed further in Section 3.3.

3.0 Environmental Monitoring Summary

3.1 Groundwater Monitoring

The groundwater monitoring program at the Weldon Spring Site includes sampling and analysis of water collected from wells at the Chemical Plant, the Quarry, adjacent properties, and selected springs in the vicinity of the Chemical Plant. The groundwater monitoring program is formally defined in the LTS&M Plan (DOE 2005a).

3.1.1 Chemical Plant Groundwater

EPA signed the GWOU ROD (DOE 2004f) on February 20, 2004. The final GWOU ROD specified a remedy of MNA with ICs to limit groundwater use during the period of remediation. MNA relies on the effectiveness of naturally occurring processes to reduce contaminant concentrations over time. The GWOU ROD establishes remedial goals and performance standards for MNA.

In July 2004, DOE initiated monitoring for MNA as outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004c). This network has since been modified as presented in the *Interim Remedial Action Report for the Groundwater Operable Unit of the Weldon Spring Site* (DOE 2005d).

3.1.1.1 Hydrogeologic Description

The Chemical Plant Site is in a physiographic transitional area between the Dissected Till Plains of the Central Lowlands province to the north and the Salem Plateau of the Ozark Plateaus province to the south. Subsurface flow and transport in the Chemical Plant area occurs primarily in the carbonate bedrock. The unconsolidated surficial materials are clay-rich, mostly glacially derived units, which are generally unsaturated beneath the Site. These materials become saturated to the north and influence groundwater flow. The thickness of the unconsolidated materials ranges from 20 ft to 50 ft (DOE 1992a).

A groundwater divide is located along the southern boundary of the Site. Groundwater north of the divide flows north toward Dardenne Creek and ultimately to the Mississippi River, and groundwater south of the divide flows south to the Missouri River. Localized flow is controlled largely by bedrock topography. Groundwater movement is by generally diffuse flow with localized zones of discrete fracture-controlled flow.

The aquifer of concern beneath the Chemical Plant is the shallow bedrock aquifer comprised of Mississippian-age Burlington-Keokuk Limestone (the uppermost bedrock unit) and the underlying Fern Glen Formation. The Burlington-Keokuk Limestone is described as having two different lithologic zones, a shallow weathered zone and an underlying unweathered zone. The weathered portion of this formation is highly fractured and exhibits solution voids and enlarged fractures. These features may also be found on a limited scale in the unweathered zone, particularly in the vicinity of buried preglacial stream channels (paleochannels). Localized aquifer properties are controlled by fracture spacing, solution voids, and preglacial weathering, including structural troughs along the bedrock-overburden interface. The unweathered portion of

the Burlington-Keokuk Limestone is thinly to massively bedded. Fracture densities are significantly less in the unweathered zone than in the weathered zone.

All monitoring wells at the Chemical Plant are completed in the Burlington-Keokuk Limestone. Most of the wells are completed in the weathered zone of the bedrock where groundwater has the greatest potential to be contaminated. Some wells screened in the unweathered zone of the Burlington-Keokuk Limestone are used to assess the vertical migration of contaminants. Where possible, monitoring wells within the boundaries of the Chemical Plant are located near historical contaminant sources and preferential flow pathways (paleochannels) to assess the movement of contaminated groundwater in the shallow aquifer. Additional wells are located outside the Chemical Plant boundary to detect and evaluate the potential off-site migration of contaminants (Figure 3–1).

Numerous springs, a common feature in carbonate terrains, are present in the vicinity of the Site. Four springs that are monitored routinely (Figure 3–2) have been historically influenced by Chemical Plant discharge water, or by groundwater, that contained one or more of the contaminants of concern.

The presence of elevated total uranium and nitrate levels at Burgermeister Spring (SP-6301), which is 1.2 miles north of the Site, indicates that discrete subsurface flow paths are present in the vicinity of the Site. Groundwater tracer tests performed in 1995 (DOE 1997) confirmed that a discrete and rapid subsurface hydraulic connection exists between the northern portion of the Chemical Plant and Burgermeister Spring. These flow paths are associated with the preglacial stream channels present beneath the Site.

3.1.1.2 Contaminants of Interest

Contaminated groundwater remains beneath the Chemical Plant. Contaminants include uranium, nitrate, TCE, and nitroaromatic compounds. Contamination in groundwater is generally confined to the shallow, weathered portion of the Burlington-Keokuk Limestone. Some contamination occurs in the deeper, unweathered portion of the bedrock, primarily beneath the former raffinate pits. The groundwater at the Chemical Plant has been contaminated by past operations that resulted in multiple source areas. Remediation activities have eliminated the sources for the groundwater contamination beneath the Site. The distribution of contaminants in the shallow aquifer at the Site is controlled by several processes, such as transformation, adsorption, desorption, dilution, or dispersion; the primary attenuation mechanisms are dilution and dispersion.

The raffinate pits were the primary historical source of uranium contamination in groundwater. Uranium entered the shallow aquifer via infiltration through the thin overburden beneath the pits. The extent of uranium in groundwater was limited because uranium is partially sorbed to the clays in the overburden materials. At locations where uranium contaminated water migrated beneath the overburden, it would enter the limestone conduit system and subsequently discharge to springs north of the Site. The oxidizing chemistry of the shallow aquifer does not provide for precipitation of uranium from solution. Uranium contaminated sediments were also discharged off-site during past operations. These sediments would accumulate in subsurface cracks and fissures in the losing stream segments and act as residual sources to groundwater and springs.

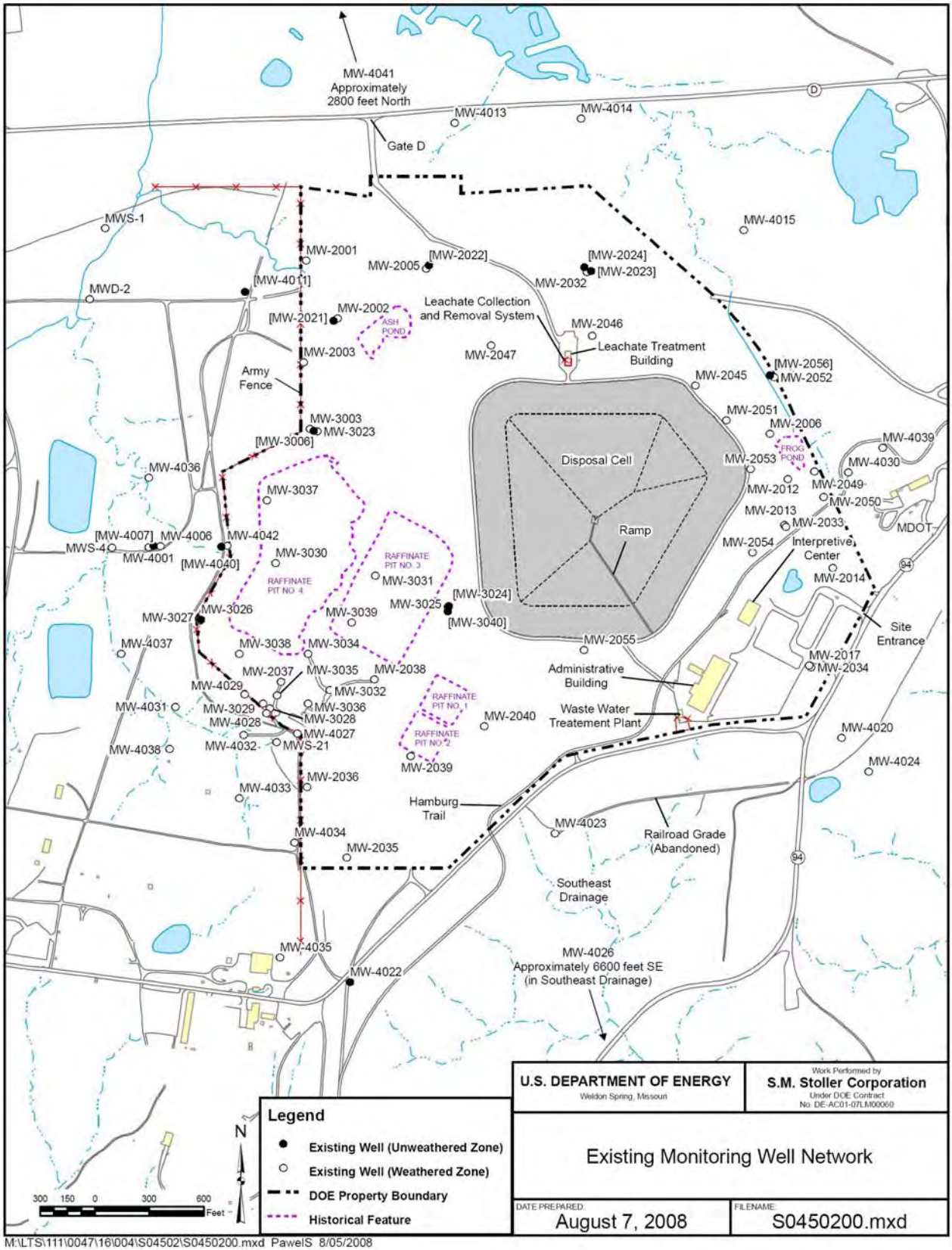

Figure 3–1. Existing Monitoring Well Network

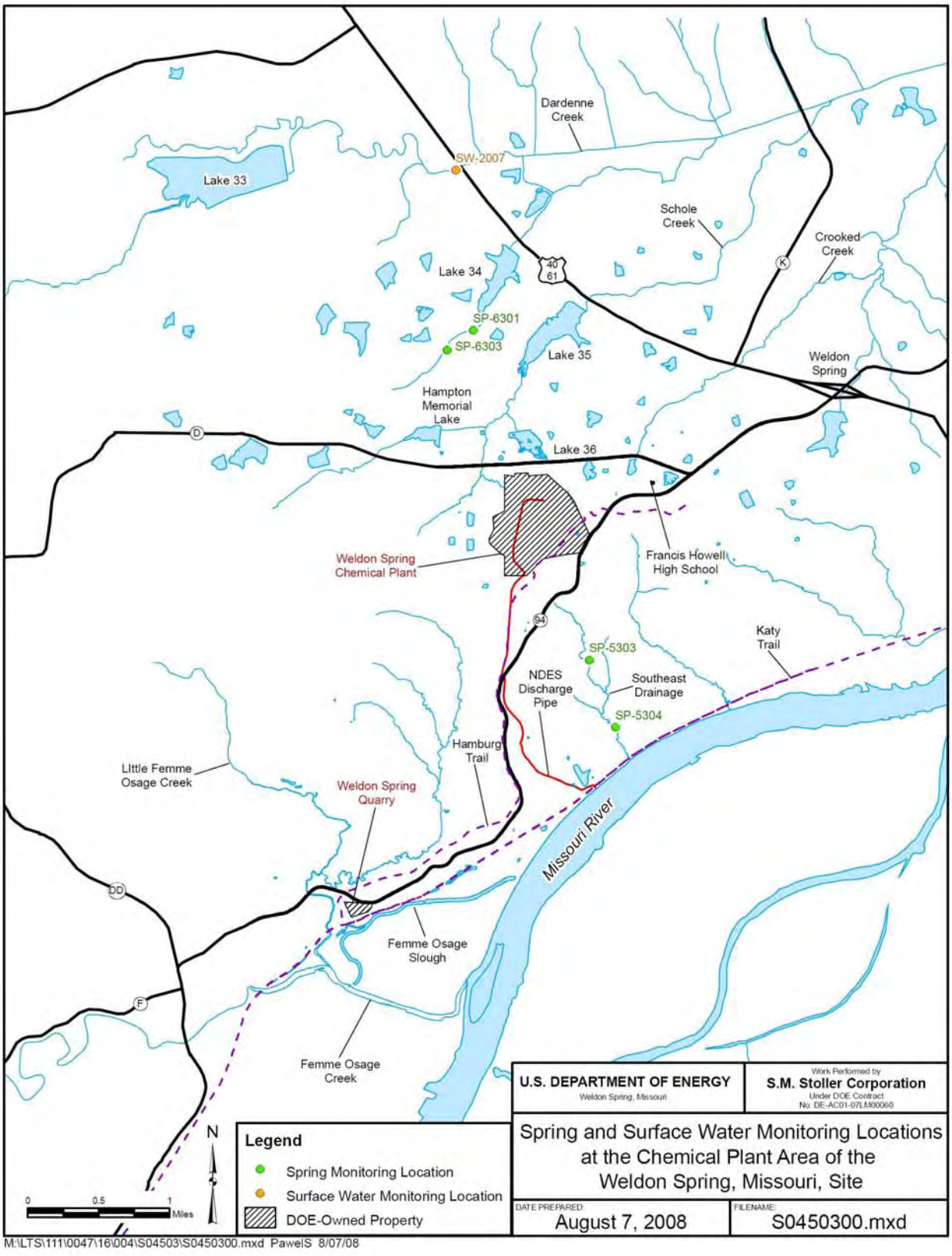

Figure 3–2. Spring and Surface Water Monitoring Locations at the Chemical Plant Area of the Weldon Spring, Missouri, Site

Nitrate is present in the groundwater near the former raffinate pits and the Ash Pond area, which are the historical source of this contaminant. Nitrate is mobile in the shallow groundwater system, as it is not readily sorbed to subsurface materials. Conditions for natural denitrification have not been identified in the shallow aquifer, so nitrate persists in groundwater and enters the limestone conduit system and subsequently discharges to springs north of the Site.

Groundwater contaminated with TCE is localized in the weathered portion of the bedrock aquifer in the vicinity of Raffinate Pit 4. The source of TCE contamination was drums that were disposed of in Raffinate Pit 4. The oxidized chemistry of the shallow bedrock aquifer does not promote biodegradation of organic compounds.

Nitroaromatic compounds (1,3-dinitrobenzene [DNB]; 2,4,6-TNT; 2,4-DNT; 2,6-DNT; and nitrobenzene) in the groundwater system coincide with former production-line locations. The presence of nitroaromatic compounds in groundwater is a result of leakage from former TNT process lines, discharges from water lines, and leaching from contaminated soils and waste lagoons. The mobility of nitroaromatic compounds in the bedrock aquifer is high due to little sorption to the bedrock materials. Microorganisms indigenous to the soils and the shallow aquifer have the ability to transform and degrade TNT and DNT.

3.1.1.3 Chemical Plant (GWOU) Monitoring Program

Monitoring at the Chemical Plant was changed in July 2004 to focus on the selected remedy of MNA. Under the new monitoring program, total uranium, nitroaromatic compounds, TCE, and nitrate (as N) have been monitored at selected locations throughout the Chemical Plant area (Table 3–1). The sampling locations target areas of highest impact in the shallow aquifer and migration pathways associated with paleochannels in the weathered unit of the Burlington-Keokuk Limestone. Deeper wells screened in the underlying unweathered unit are sampled to assess potential vertical movement. Analytical results for 2007 are discussed in Section 3.1.1.3.

The monitoring network consists of 50 wells, 4 springs, and 1 surface water location. The locations are depicted on Figure 3–1 and Figure 3–2. Each well was selected to fulfill objectives specified in the GWOU ROD (DOE 2004f) for the MNA monitoring network (Table 3–2). The objectives are as follows:

- Objective 1 is to monitor the unimpacted water quality at upgradient locations in order to maintain a baseline of naturally occurring constituents from which to evaluate changes in downgradient locations. This objective will be met by using wells located upgradient of the contaminant plumes.
- Objective 2 is to verify that contaminant concentrations are declining with time at a rate and in a manner that cleanup standards will be met in approximately 100 years, as established by predictive modeling. This objective will be met using wells at or near the locations with the highest concentrations of contaminants, both near the former source areas and along expected migration pathways. The objective will be to evaluate the most contaminated zones. Long-term trend analysis will be performed to confirm downward trends in contaminant concentration over time. Performance will be gauged against long-term trends. It is anticipated that some locations could show temporary upward trends due to the recent source control remediation, ongoing dispersion, seasonal fluctuations, analytical variability, or other factors. However, concentrations are not expected to exceed historical maximums.

Table 3–1. Monitoring Program for GWOU MNA Remedy

Location	Sampling Frequency[a]	Monitoring Parameters							
		TCE	Nitrate (as N)	Uranium	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB
MW-2012	S				✔	✔	✔	✔	✔
MW-2014	S						✔	✔	
MW-2017	S				✔	✔	✔	✔	✔
MW-2021	S		✔						
MW-2022	S		✔		✔	✔			
MW-2023	S				✔	✔	✔	✔	✔
MW-2032	S				✔	✔	✔	✔	✔
MW-2035	S	✔	✔	✔			✔		
MW-2038	S		✔				✔		
MW-2040	S		✔			✔			
MW-2046	S					✔			
MW-2050	S						✔	✔	
MW-2051	S				✔	✔	✔	✔	✔
MW-2052	S						✔	✔	
MW-2053	S					✔	✔	✔	
MW-2054	S						✔	✔	
MW-2056	S				✔	✔	✔	✔	✔
MW-3003	S		✔	✔					
MW-3006	S	✔	✔	✔			✔		
MW-3024	S			✔					
MW-3030	S	✔		✔			✔		
MW-3031	S	✔		✔					
MW-3034	S	✔	✔				✔		
MW-3037	S	✔		✔			✔		
MW-3039	S						✔		
MW-3040	Q	✔	✔	✔					
MW-4007	S	✔	✔						
MW-4013	S		✔				✔	✔	✔
MW-4014	S		✔		✔	✔	✔	✔	✔
MW-4015	S						✔	✔	✔
MW-4022	S		✔	✔					
MW-4023	S		✔	✔					
MW-4026	S			✔					
MW-4029	S	✔	✔						
MW-4031	S		✔						
MW-4036	S	✔	✔	✔			✔		
MW-4039	S				✔	✔	✔	✔	✔
MW-4040	Q	✔	✔	✔			✔		
MW-4041	S	✔	✔	✔	✔	✔	✔	✔	✔
MW-4042	Q	✔	✔	✔	✔	✔	✔	✔	✔
MWS-1	S	✔	✔	✔			✔		
MWS-4	S	✔	✔	✔					
MWD-2	S		✔	✔					
SP-5303	S			✔					
SP-5304	S			✔					
SP-6301	S	✔	✔	✔	✔	✔	✔	✔	✔
SP-6303	S	✔	✔	✔	✔	✔	✔	✔	✔
SW-2007	S			✔					

[a]Monitoring frequencies may be decreased to annual or biennial on the basis of trends in at least the first 2 years of data.
S = semiannual Q = quarterly

Table 3–2. MNA Monitoring Locations for the GWOU

Objective 1	Objective 2	Objective 3	Objective 4	Objective 5	Objective 6
MW-2017	MW-2012	MW-2032	MW-2021	SP5303	MW-2005
MW-2035	MW-2014	MW-2051	MW-2022	SP5304	MW-2055
MW-4022	MW-2038	MW-3031	MW-2023	SP6301	MW-3025
MW-4023	MW-2040	MW-3037	MW-2056	SP6303	MW-3038
	MW-2046	MW-4013	MW-3006	SW-2007[b]	MW-4001
	MW-2050	MW-4014	MW-4007		MW-4011
	MW-2052	MW-4015	MW-4042		MW-4020
	MW-2053	MW-4026	MWD-2		MW-4037
	MW-2054	MW-4036			
	MW-3003	MW-4039			
	MW-3024	MW-4041			
	MW-3030	MWS-1			
	MW-3034	MWS-4			
	MW-3039				
	MW-3040				
	MW-4013[a]				
	MW-4029				
	MW-4031				
	MW-4036[a]				
	MW-4040				

[a]Location is also an Objective 3 location.
[b]Location is on Dardenne Creek immediately upstream of Highway 40/61, approximately 2.1 miles north of the Site.

- Objective 3 is to ensure that lateral migration remains confined to the current area of impact. Contaminants are expected to continue to disperse within known preferential flow paths associated with bedrock lows (paleochannels) in the upper Burlington-Keokuk Limestone and become more dilute over time as rain events continue to recharge the area. This objective will be met by monitoring various downgradient fringe locations that are either not impacted or minimally impacted. Contaminant impacts in these locations are expected to remain minimal or nonexistent.
- Objective 4 is to monitor locations underlying the impacted groundwater system to confirm that there is no significant vertical migration of contaminants. This will be evaluated using deeper wells screened in and influenced by the unweathered zone. No significant impacts should be observed at these locations.
- Objective 5 is to monitor contaminant levels at the impacted springs that are the only potential points of exposure under current land use conditions. The springs discharge groundwater that includes contaminated groundwater originating at the Chemical Plant area. Presently, contaminant concentrations at these locations are protective of human health and the environment under current recreational land uses. Continued improvement of the water quality in the affected springs should be observed.
- Objective 6 is to monitor for hydrologic conditions at the Site over time in order to identify any changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevation of the monitoring network will be measured to establish that groundwater flow is not changing significantly and resulting in changes in contaminant migration.

The monitoring network is designed to provide data to show that either natural attenuation processes are acting as predicted or to trigger the implementation of contingencies when these processes are not acting as predicted (e.g., unexpected expansion of the plume or sustained

increases in concentrations within the area of impact). The data analysis and interpretation will satisfy the following:

- Baseline conditions (Objective 1) have remained unchanged.
- Performance monitoring locations (Objective 2) indicate that concentrations within the area of impact are decreasing as expected.
- Detection monitoring locations (Objectives 3, 4, and 5) indicate when a trigger has been exceeded indicating unacceptable expansion of the area of impact.
- Hydrogeologic monitoring locations (Objectives 1, 4, and 6) indicate any changes in groundwater flow that might affect the protectiveness of the MNA remedy at the Site over time.

3.1.1.4 Baseline Monitoring Results for the GWOU

Baseline conditions are monitored in four upgradient wells to determine if possible changes in downgradient areas of impact are the result of upgradient conditions. The objective of this monitoring is to determine if baseline conditions have remained unchanged. Each of these wells was sampled twice during 2007. The annual average concentration for each parameter is presented in Table 3–3. The average concentrations measured in 2007 are similar to those from 2006 and indicate no change in upgradient groundwater quality.

Table 3–3. Summary of Baseline Monitoring Locations for the GWOU MNA Remedy

Location	MW-2017	MW-2035	MW-4022	MW-4023
Zone	Weathered	Weathered	Unweathered	Weathered
Number of Samples	2	2	2	2
Parameters				
Uranium (pCi/L)	NA	0.44	5.50	1.65
Nitrate (as N) (mg/L)	NA	0.59	0.50	1.40
TCE (µg/L)	NA	ND	NA	NA
1,3-DNB (µg/L)	ND	ND	NA	NA
2,4,6-TNT (µg/L)	ND	ND	NA	NA
2,4-DNT (µg/L)	ND	ND	NA	NA
2,6-DNT (µg/L)	ND	ND[1]	NA	NA
Nitrobenzene (µg/L)	ND	ND	NA	NA

[1]detectable concentration reported for 12/07 sample – see text for discussion
ND = Analyte not detected above method detection limit
NA = Analyte not analyzed

A detectable concentration of 2,6-DNT was reported for background location MW-2035. This location was re-sampled in January 2008 to verify the positive detection of the nitroaromatic compound. The result from the re-sampling event was non-detect (< 0.09 µg/L). It was concluded that the positive detect reported for 2,6-DNT was anomalous and did not represent the groundwater quality at the upgradient locations. Subsequent data will continue to be evaluated.

3.1.1.5 Performance Monitoring Results for the GWOU

The performance of the MNA remedy is assessed through the sampling of the Objective 2 monitoring wells. Objective 2 wells are located within the areas of impact and monitor both the weathered and unweathered units of the Burlington-Keokuk Limestone. Objective 2 of the MNA

strategy is to verify that contaminant concentrations are declining or remaining stable as expected and that cleanup standards will be met in a reasonable timeframe.

Contaminant concentrations are monitored using 20 wells (Figure 3–1) situated within the areas of highest impact of each contaminant plume at the Site. These wells were sampled at least semiannually during 2007. The data is discussed in the following sections.

Uranium

The area of uranium impact is located in the former Raffinate Pits area. Uranium levels exceed the MCL of 20 pCi/L in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the uranium data for 2007 is presented in Table 3–4.

Table 3–4. 2007 Uranium Data from Objective 2 Wells

Location	Uranium Activity (pCi/L)				
	S1		S2		Average
Weathered Unit					
MW-3003	3.0		4.7		3.85
MW-3024	84.6		97.5		91.0
MW-3030	40.8		40.1		40.4
Unweathered Unit					
	Q1	**Q2**	**Q3**	**Q4**	
MW-3040	94.1	81.2	92.1	100	91.8
MW-4040	238	234	244	342	264

S1, S2 = semiannual sampling events
Q1–Q4 = quarterly sampling events

The highest uranium impact in the weathered unit is measured in MW-3024. This well has shown variable uranium levels (Figure 3–3); however, data from the last 5 years indicates an upward trend (Section 3.1.1.7). The remaining Objective 2 weathered wells show gradually decreasing uranium levels over time, and the downward trends in data are supported by trend analysis. Since 2000, the levels in MW-3003 have consistently been less than the MCL. The levels measured in wells MW-3003 and MW-3030 are similar to those measured in 2006.

Uranium impact is greatest in the two unweathered wells that were installed beneath and immediately downgradient of the former raffinate pits (Figure 3–4) where uranium levels continue to exceed the MCL of 20 pCi/L. Uranium in MW-3040 has been stable since installation of the well in 2004. The uranium level in MW-4040, located downgradient of the area of impact in the weathered unit, has shown an upward trend since installation of the well in 2004. These wells will continue to be monitored quarterly during 2008, to establish baseline.

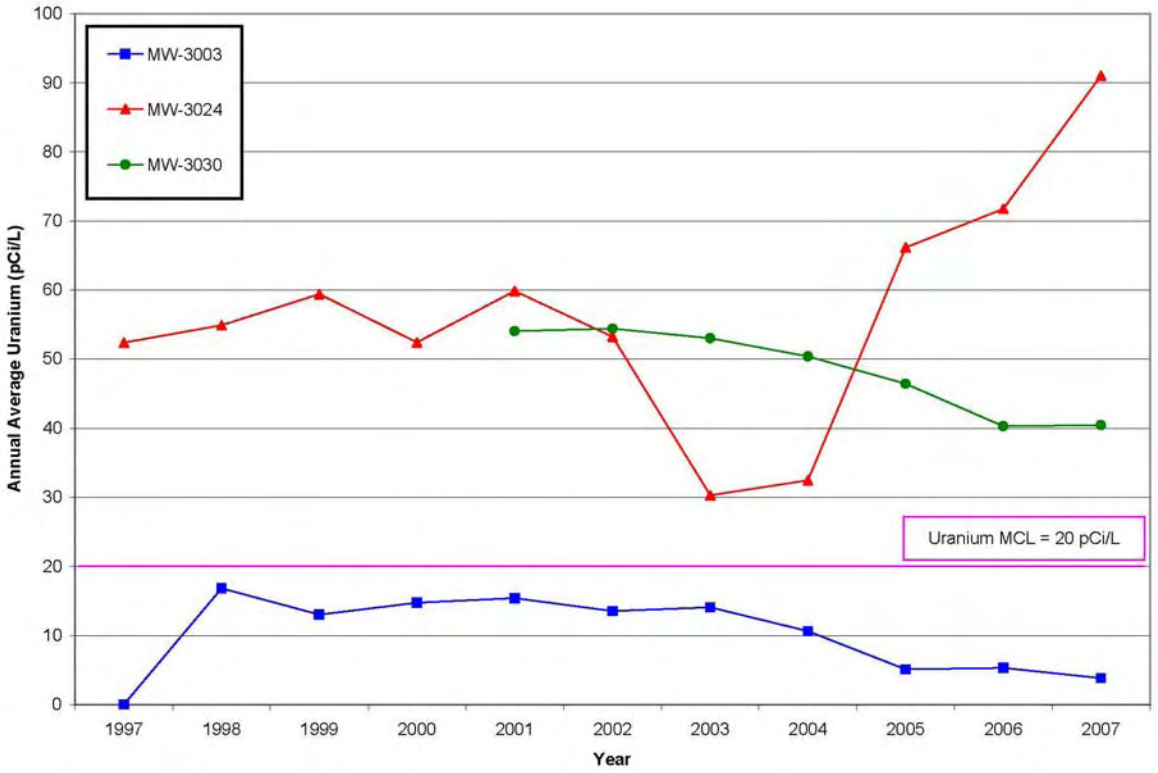

Figure 3–3. Annual Average Uranium Levels in Objective 2 Wells Screened in the Weathered Unit (1997−2007)

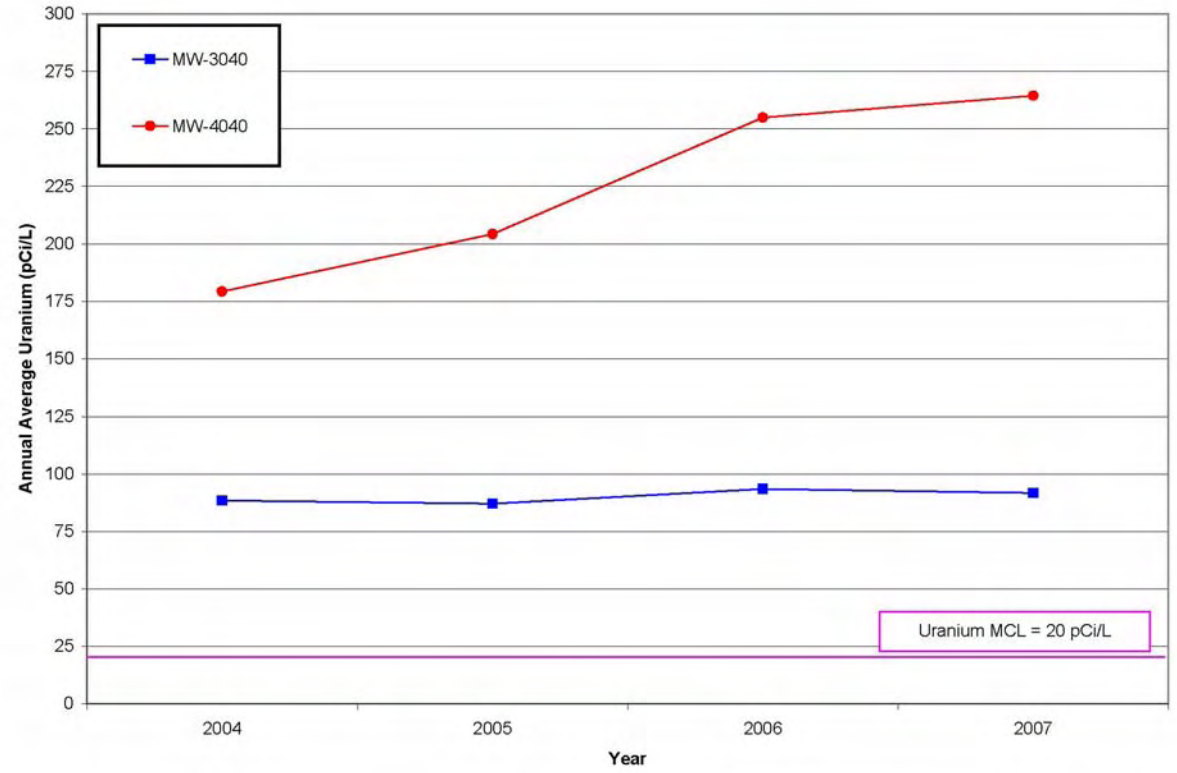

Figure 3–4. Annual Average Uranium Levels in Objective 2 Wells Screened in the Unweathered Unit (2004−2007)

Nitrate (as N)

The highest concentrations of nitrate have been measured in the vicinities of the raffinate pits and Ash Pond, which are the historical sources of this contaminant. The higher mobility of nitrate as compared to other contaminants at the Site has resulted in a larger distribution in the shallow aquifer. Nitrate levels exceed the MCL of 10 milligrams per liter (mg/L) (for nitrate as N) in both the weathered and unweathered units of the Burlington-Keokuk Limestone. A summary of the nitrate data for 2007 is presented in Table 3–5.

Table 3–5. 2007 Nitrate Data from Objective 2 Wells

Location	Nitrate Concentration (mg/L)				
	S1		S2		Average
Weathered Unit					
MW-2038	478		602		540
MW-2040	80.5		131		106
MW-3003	498		866		682
MW-3034	242		253		248
MW-4013	89.3		75.6		82.4
MW-4029	496		870		683
MW-4031	130		185		158
MW-4036	19.4		66.3		42.8
Unweathered Unit					
	Q1	**Q2**	**Q3**	**Q4**	
MW-3040	181	150	161	1,050[1]	164
MW-4040	85.6	74.1	72.7	148	95.1

[1]Data reported for the fourth-quarter sampling was not used in this report. Subsequent data from 2008 supports that the value was anomalous and is not considered representative of actual groundwater quality.
S1, S2 = semiannual sampling events
Q1–Q4 = quarterly sampling events

Nitrate concentrations are highest in the weathered unit of the Burlington-Keokuk Limestone. The highest concentrations in the weathered unit are measured in wells that are located in the former Raffinate Pits area (MW-2038, MW-3003, MW-3034, and MW-4029) (Figure 3–5). Data from the last 5 years supports a downward trend in well MW-2040; the remainder of the locations has relatively stable concentrations. Nitrate in wells MW-3003 and MW-4029 increased during 2007, but no upward trend was determined to be present at either location. Both wells are situated along preferential flow pathways downgradient of the raffinate pits, and the movement of contaminants is not unexpected.

Nitrate exceeds the MCL in the two unweathered wells located in the Raffinate Pits area. The nitrate concentrations in MW-3040 have decreased since installation of the well, and this decrease is supported by trend analysis. Nitrate concentrations in MW-4040 have remained stable (Figure 3–6). These wells will continue to be monitored more frequently during 2008, to continue to establish baseline.

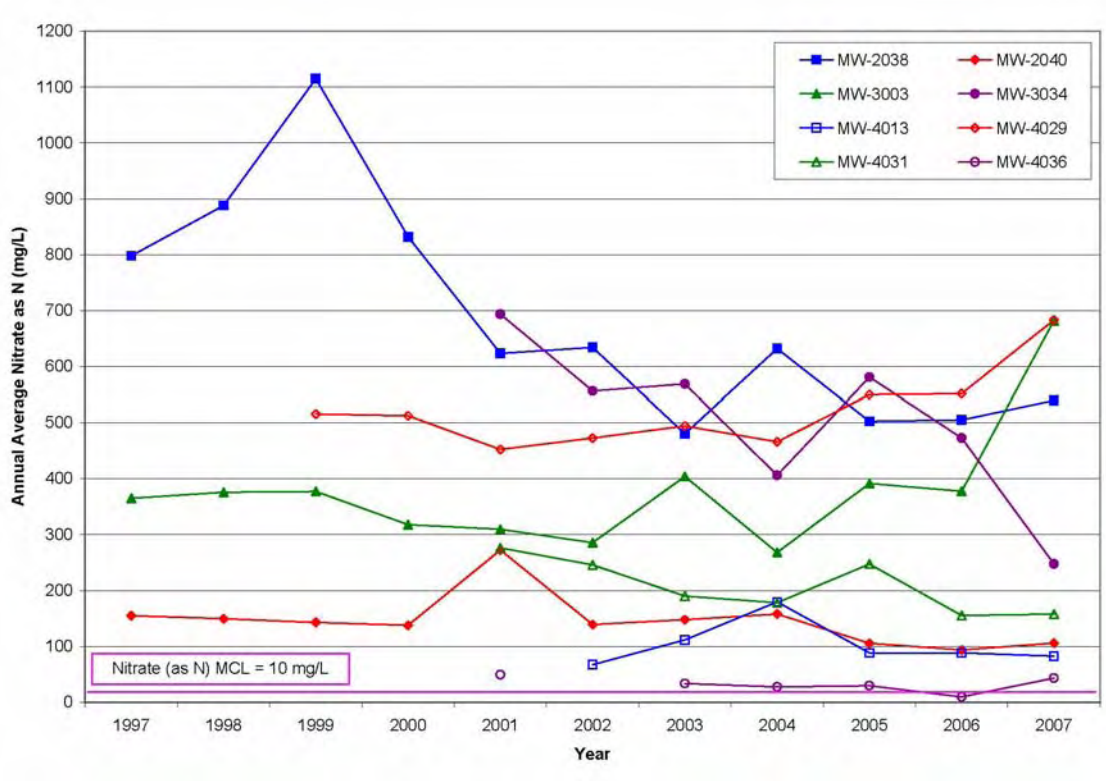

Figure 3–5. Annual Average Nitrate Concentrations in Objective 2 Wells Screened in the Weathered Unit (1997−2007)

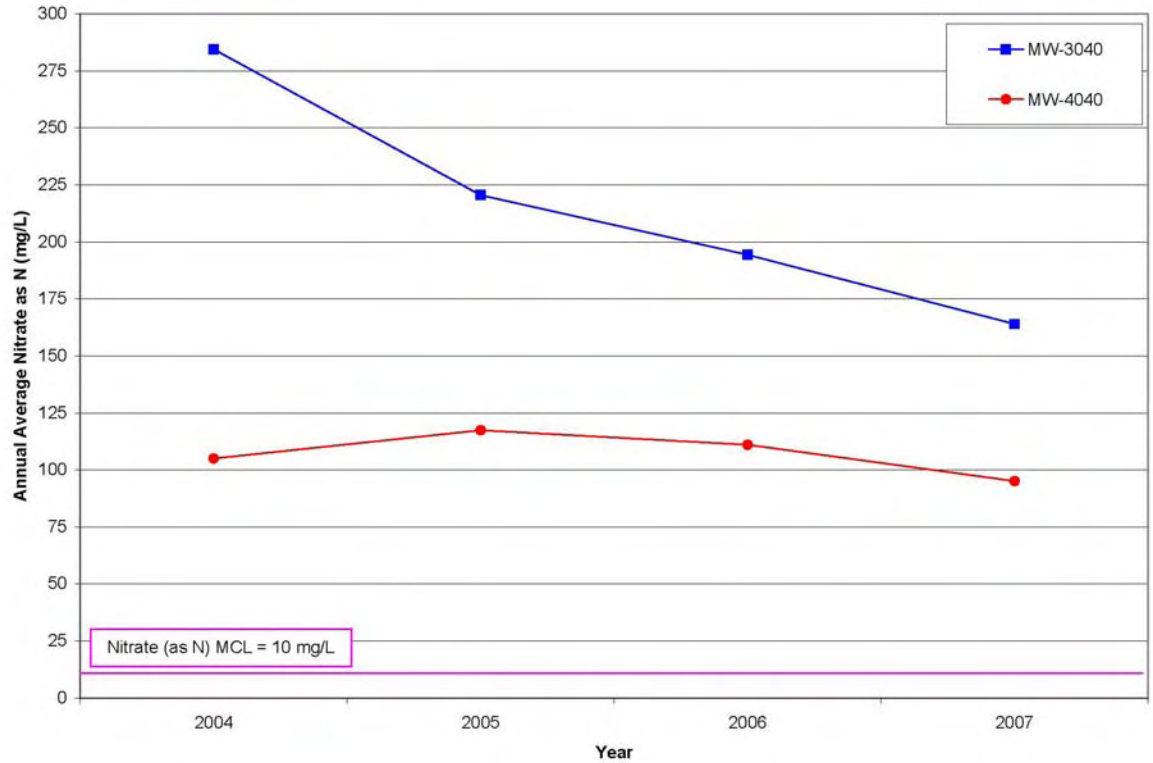

Figure 3–6. Annual Average Nitrate Concentrations in Objective 2 Wells Screened in the Unweathered Unit (2004−2007)

Trichloroethylene

TCE contamination in the shallow groundwater is located in the vicinity of Raffinate Pit 4, where drums containing TCE are suspected to have been discarded. TCE impact is detected in only the weathered unit of the Burlington-Keokuk Limestone. A summary of the TCE data for 2007 is presented in Table 3–6.

Table 3–6. 2007 TCE Data from Objective 2 Wells

Location	TCE Concentration (µg/L)			
	S1	S2		Average
MW-3030	700	ND[1]	350	525
MW-3034	210	190	240	213
MW-4029	1200	550	540	763

[1]Result not considered representative; not used in average
S1 = First sampling event
S2 = Second sampling event

TCE impact is highest in MW-4029, located along a preferential flow pathway in the area. This location exceeded the trigger of 1,000 µg/L established for Objective 2 wells during the first sampling event; however, results from two subsequent sampling events were similar to previous concentrations. Even with the increased concentrations at MW-4029 during 2007, no upward trends were identified in the data. The TCE concentrations in MW-3030 and MW-3034 have been variable over time (Figure 3–7); however, some changes are a result of rebound from field studies performed in 2001 and 2002.

1,3-Dinitrobenzene

Groundwater impacted by 1,3-dinitrobenzene (DNB) that exceeds the cleanup standard of 1.0 µg/L is located in a discrete portion of the Frog Pond area, where a TNT production line was located. Nitroaromatic compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 1,3-DNB data for 2007 is presented in Table 3–7.

Table 3–7. 2007 1,3-DNB Data from Objective 2 Wells

Location	1,3-DNB Concentration (µg/L)		
	S1	S2	Average
MW-2012	0.16	No data	0.16

[1]Data was rejected during the validation process.
S1, S2 = semiannual sampling events

Concentrations of 1,3-DNB have fluctuated in well MW-2012 (Figure 3–8). Starting in 2006, the average concentration has decreased below the cleanup standard of 1.0 µg/L. Decreases in nitroaromatic compounds, observed at this location since 2004, are the result of surface infiltration. Downward trends associated with MW-2012 are not considered to be the result of attenuation processes, and subsequent data may return to near historical levels (DOE 2006b).

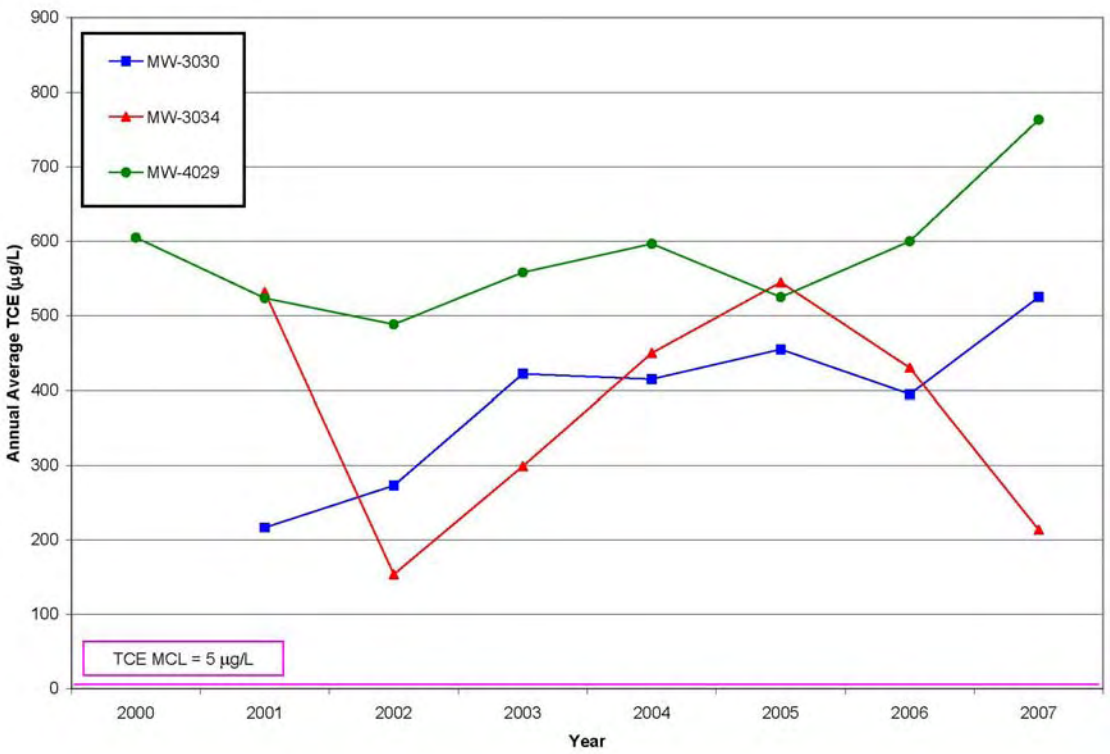

Figure 3–7. Annual Average TCE Concentrations in Objective 2 Wells (2000−2007)

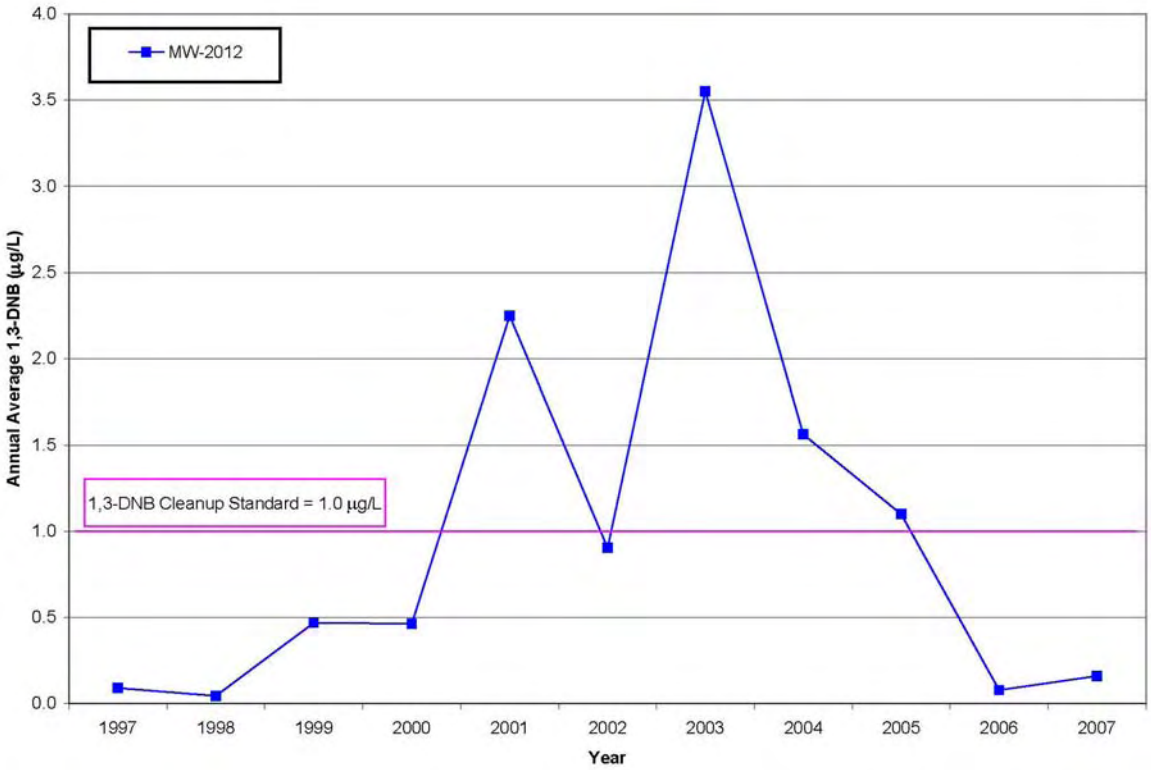

Figure 3–8. Annual Average 1,3-DNB Concentrations in Objective 2 Well MW-2012 (2000−2006)

2,4,6-Trinitrotoluene

Groundwater impacted by 2,4,6-TNT that exceeds the cleanup standard of 2.8 µg/L is located in two discrete portions of the Frog Pond area. Nitroaromatic compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 2,4,6-TNT data for 2007 is presented in Table 3–8.

Table 3–8. 2007 2,4,6-TNT Data from Objective 2 Wells

Location	2,4,6-TNT Concentration (µg/L)		
	S1	S2	Average
MW-2012	11	31	21
MW-2046	5.2	No data	5.2
MW-2053	2.4	12	7.2

[1]Data was rejected during the validation process.
S1,S2 = semiannual sampling events

The highest 2,4,6-TNT concentrations continue to be associated with MW-2012, which is adjacent to where TNT production buildings once stood. Data collected between 2004 and 2006 showed a substantial decrease (Figure 3–9), which is suspected to be associated with surface infiltration. In 2007, a slight increase occurred in MW-2012. Concentrations of TNT in MW-2046 and MW-2053 rebound to concentrations similar to those measured in 2004.

2,4-Dinitrotoluene

Groundwater impacted by 2,4-DNT that exceeds the cleanup standard of 0.11 µg/L is located in the Frog Pond and Raffinate Pits areas of the Chemical Plant. TNT production lines were located in both of these areas. Nitroaromatic-compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 2,4-DNT data for 2007 is presented in Table 3–9.

Table 3–9. 2007 2,4-DNT Data from Objective 2 Wells

Location	2,4-DNT Concentration (µg/L)		
	S1	S2	Average
Frog Pond Area			
MW-2012	19	380	200
MW-2014	0.14	1.0	0.57
MW-2050	24	42	33
MW-2052	0.06	No data	0.06
MW-2053	No data	No data	not calculated
MW-2054	No data	No data	0.47
Raffinate Pits Area			
MW-2038	0.22	1.0	0.61
MW-3030	1.1	1.7	1.4
MW-3034	No data	(a)	not calculated
MW-3039	ND	1.1	0.58

[1]Data was rejected during the validation process .
ND = non-detect
S1, S2 = semiannual sampling events

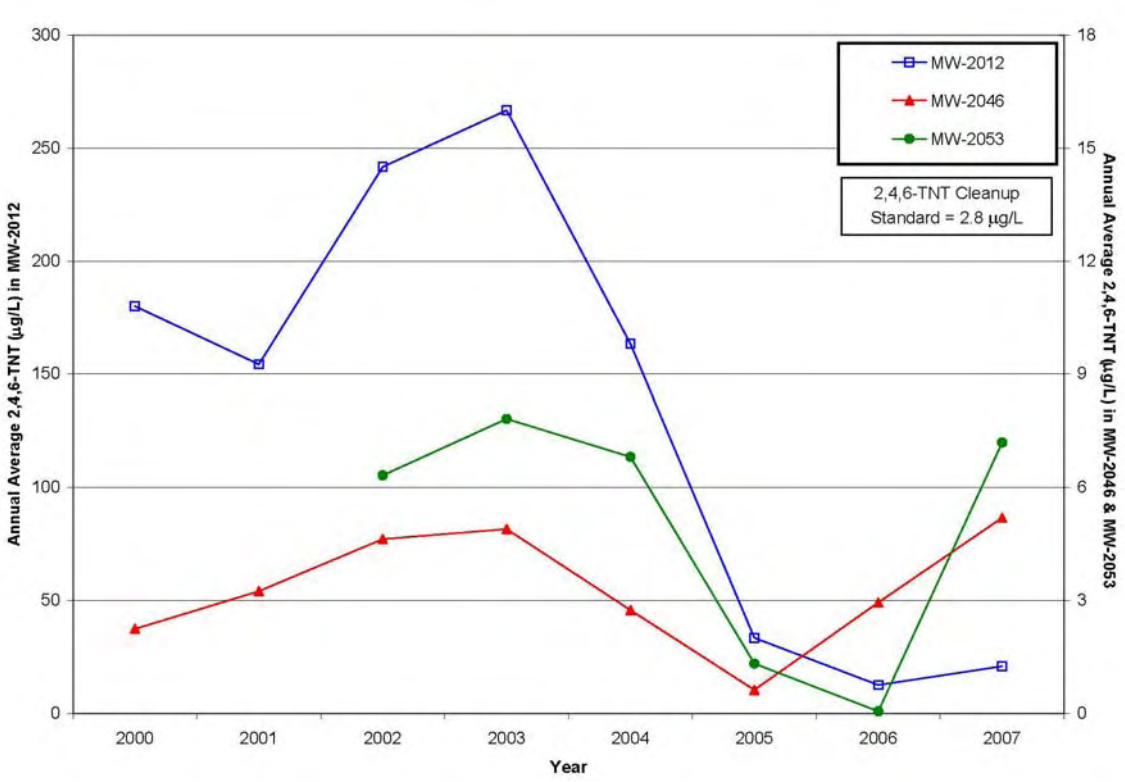

Figure 3–9. Annual Average 2,4,6-TNT Concentrations in Objective 2 Wells (2000−2006)

The highest 2,4-DNT impact has been associated with MW-2012 in the Frog Pond area. Data from recent years has likely been affected by surface infiltration, as previously discussed, and has resulted in decreased 2,4-DNT concentrations at this location (Figure 3–10). Levels increased slightly during 2007 and continue to exceed the cleanup standard of 0.11 µg/L.

Of the remainder of the wells in the Frog Pond area, MW-2050 has the highest 2,4-DNT concentrations (Figure 3–11). In general, data from the last few years indicate that these concentrations may be stabilizing in many of the wells. Concentrations of 2,4-DNT in MW-2054 continue to be lower than previously measured. The continued decrease in MW-2054 could not be explained. This well is located upgradient of the subsidence feature near MW-2012. Data from 2007 indicate that concentrations have stabilized since 2005. The remainder of the monitoring locations have stable concentrations over time.

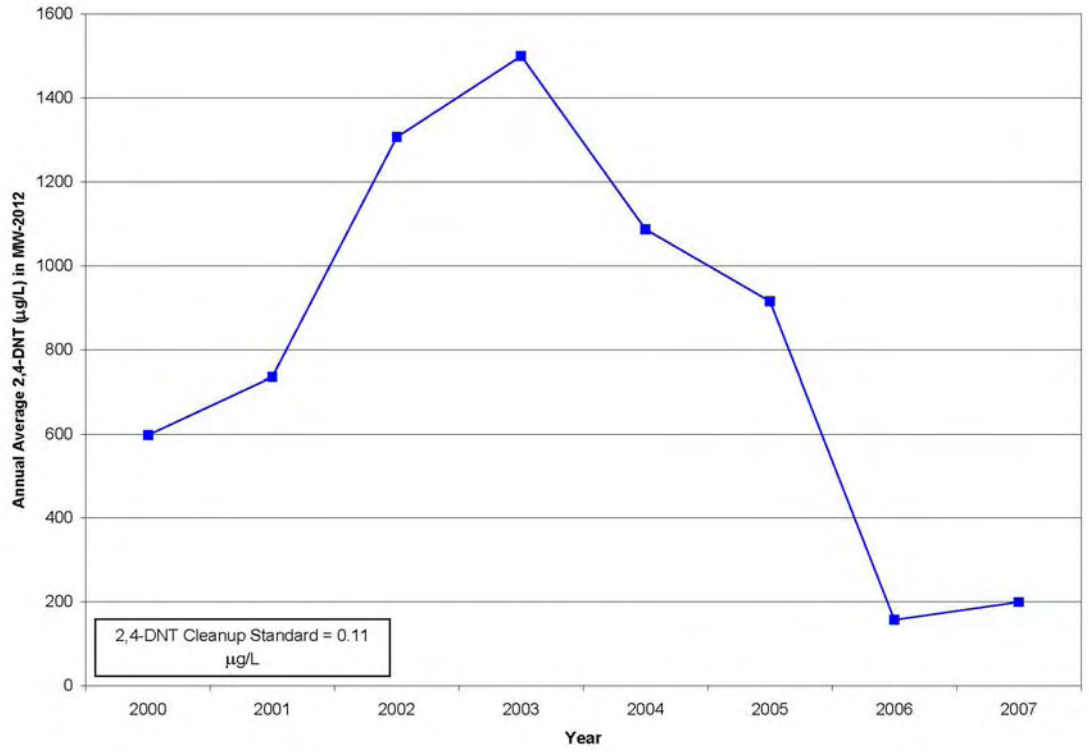

Figure 3–10. Annual Average 2,4-DNT Concentrations in Objective 2 Well MW-2012 (2000−2006)

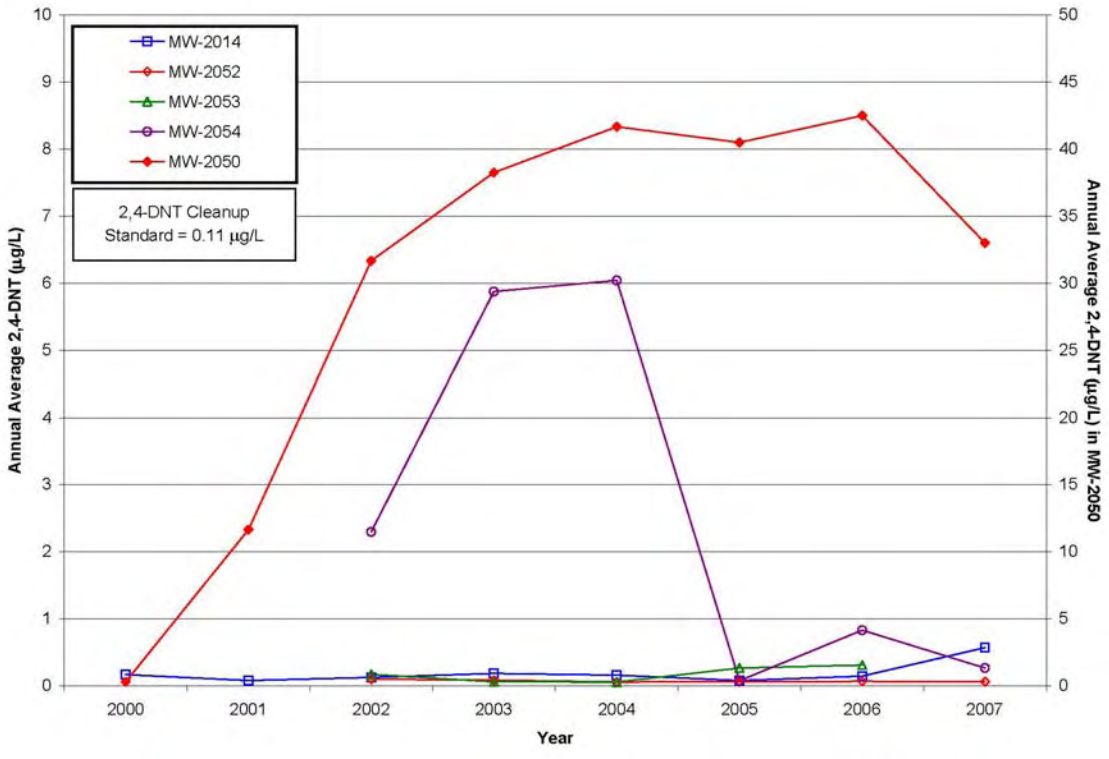

Figure 3–11. Annual Average 2,4-DNT Concentrations in Objective 2 Wells in the Frog Pond Area (2000−2006)

Elevated concentrations of 2,4-DNT are also present in the former Raffinate Pits area Figure 3–12). Portions of TNT-Production Lines #3 and #4 were located in this area of the Site. Concentrations of 2,4-DNT continue to exceed the cleanup standard of 0.11 µg/L in this area. Concentrations in wells MW-2038, MW-3030, and MW-3039 are higher than those in 2006. Concentrations over the past 5 years have been relatively stable in many of the wells. No 2,4-DNT data were reported for MW-3034 as the results from both sampling events were rejected during the verification and validation processes.

2,6-Dinitrotoluene

Groundwater impacted by 2,6-DNT that exceeds the cleanup standard of 1.3 µg/L is located in a discrete portion of the Frog Pond area. Nitroaromatic-compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the 2,6-DNT data for 2007 is presented in Table 3–10.

Table 3–10. 2007 2,6-DNT Data from Objective 2 Wells

Location	2,6-DNT Concentration (µg/L)		
	S1	S2	Average
MW-2012	85	360	222
MW-2014	0.38	1.5	0.94
MW-2050	52	57	54
MW-2052	0.18	1.1	0.64
MW-2053	10	10	10
MW-2054	ND	7.9	4.0

ND = non-detect
S1, S2 = semiannual sampling events

Concentrations of 2,6-DNT have been the highest in MW-2012, but they have decreased substantially since 2004 (Figure 3–13). The behavior of the concentrations over time for 2,6-DNT in this well and others is similar to the behavior of 2,4-DNT. The concentrations have been affected by surface infiltration since 2004. Concentrations reported in 2007 indicated a slight rebound in 2,6-DNT.

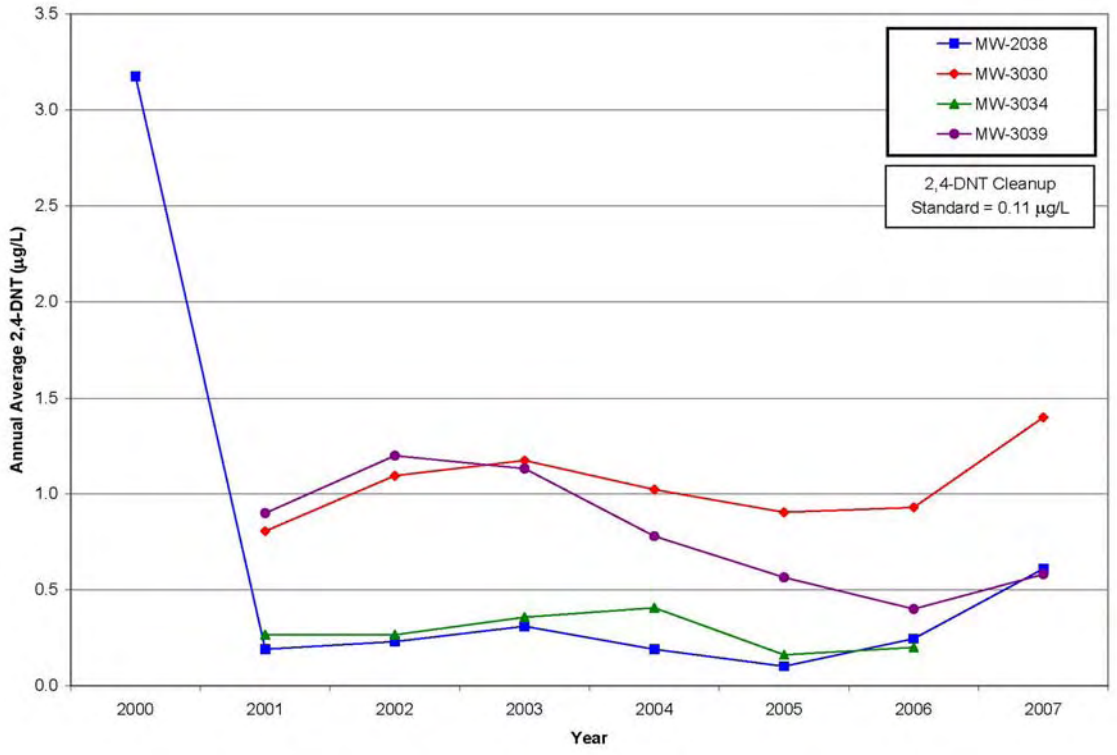

Figure 3–12. Annual Average 2,4-DNT Concentrations in Objective 2 Wells in the Raffinate Pits Area (2000−2006)

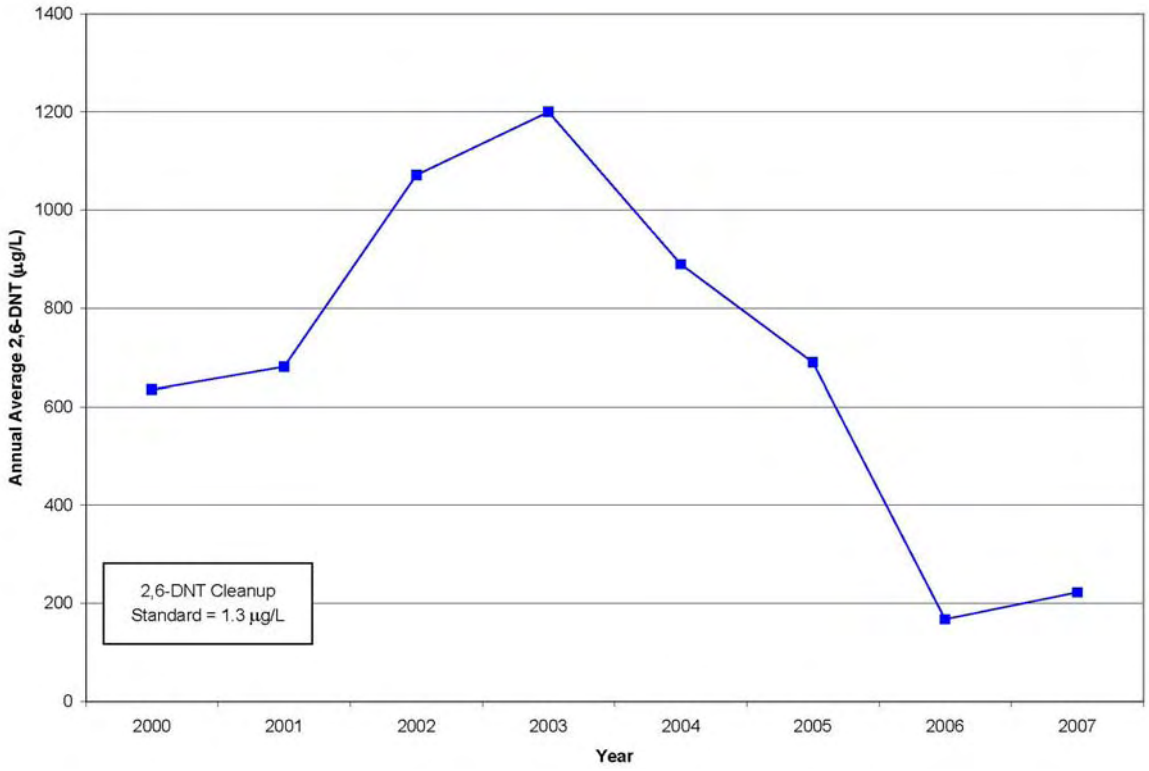

Figure 3–13. Annual Average 2,6-DNT Concentrations in Objective 2 Well MW-2012 (2000−2006)

Increases in concentrations are indicated in MW-2050 (Figure 3–14), which has the next highest 2,6-DNT concentrations in the Frog Pond area. Data from the last 5 years indicate an upward trend at this location. This well is located downgradient of former Waste Lagoon #1, which could be contributing to this location. The variable concentrations in MW-2054 could not be explained. Concentrations in MW-2014, MW-2052, and MW-2053 are relatively stable although an upward trend has been calculated at MW-2053.

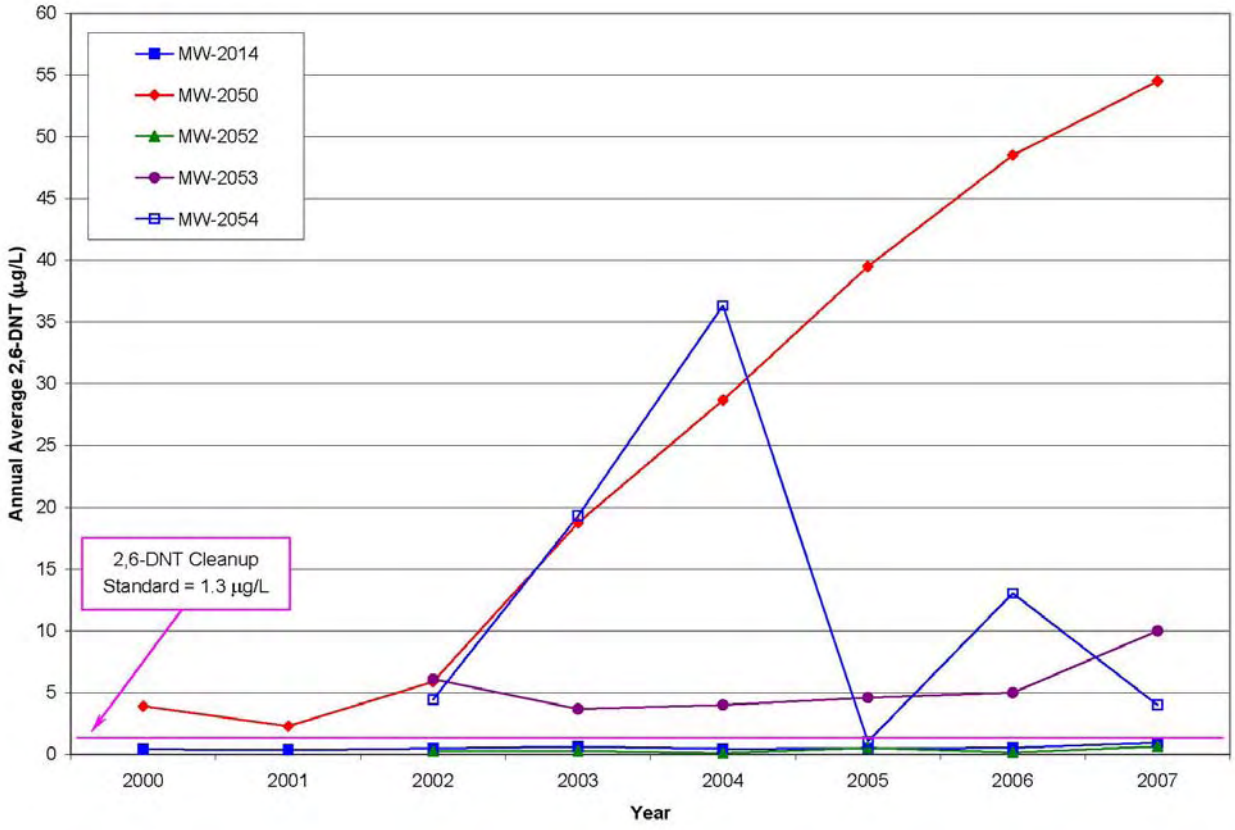

Figure 3–14. Annual Average 2,6-DNT Concentrations in Objective 2 Wells (2000−2006)

Nitrobenzene

Groundwater impacted by nitrobenzene (NB) that exceeds the cleanup standard of 17 µg/L is located in a discrete portion of the Frog Pond area. Nitroaromatic compound impact is isolated to the weathered unit of the Burlington-Keokuk Limestone. A summary of the NB data for 2007 is presented in Table 3–11. NB has not been detected at this location since 2002 when a one-time level of 69 µg/L was detected.

Table 3–11. NB Data from Objective 2 Wells

Location	NB Concentration (µg/L)		
	S1	S2	Average
MW-2012	ND	ND	< 0.068

ND = non-detect

3.1.1.6 Detection Monitoring Results for the GWOU

Detection monitoring consists of sampling to fulfill Objectives 3, 4, and 5 of the MNA strategy. Wells along the fringes and downgradient (both laterally and vertically) of the areas of impact are monitored to ensure that lateral and vertical migration remains within the current area of impact and that expected lateral downgradient migration (due to dispersion) within the paleochannels is minimal or nonexistent. Springs and a surface water location on Dardenne Creek are also monitored as part of this program, as these are the closest groundwater discharge points for the shallow aquifer in the vicinity of the Chemical Plant. These locations are monitored to ensure that concentrations remain protective of human health and the environment and that water quality continues to improve.

Contaminant concentrations are monitored using 21 wells, 4 springs, and 1 surface water location situated along the fringes or downgradient of the areas of highest impact of the different contaminant plumes at the Site. These locations were sampled semiannually during 2007, unless noted. The data is discussed in the following sections.

During 2007, well MW-4042 was drilled and installed. This well is located west of the former raffinate pits area. It is screened at the base of the unweathered unit of the Burlington-Keokuk Limestone. It is intended to be an Objective 4 well providing data for groundwater beneath the area of impact.

Uranium

Data from the detection monitoring network indicate that uranium is migrating along the preferential flow pathways (paleochannels) as expected. The average uranium level in MW-4036 (28.0 pCi/L) does exceed the MCL of 20 pCi/L. No increases were identified in the remainder of the wells screened in either the weathered or unweathered units. A summary of the uranium data is presented in Table 3–12.

The levels of uranium measured at MW-4036 during 2007 were 54.8 pCi/L (in May 2007) and 1.3 pCi/L (in October 2007). The result from the May 2007 sampling event was greater than the trigger of 50 pCi/L for the closer Objective 3 wells. A value of 80.2 pCi/L was measured at this location in May 2003. This well is screened in the weathered unit and is located immediately downgradient of the highest uranium impact in the weathered and unweathered units. Elevated nitrate concentrations indicate that this well is connected to groundwater in the former Raffinate Pits area. Variable uranium and nitrate data have been reported at this location since installation of the well (Figure 3–15).

Table 3–12. 2007 Uranium Data for Objective 3, 4, and 5 Locations

Sample ID	Unit/Location	Average (pCi/L)	Number of Samples
Weathered Unit			
MW-3031	Fringe	2.4	2
MW-3037	Fringe	2.4	2
MW-4026	Southeast Drainage (alluvium)	ND	2
MW-4036	Downgradient	28.0	2
MW-4041	Downgradient	1.5	2
MWS-1	Downgradient	0.73	2
MWS-4	Downgradient	0.38	2
Unweathered Unit			
MW-3006	Fringe	0.68	2
MW-4042	Downgradient	2.1	2
MWD-2	Downgradient	0.92	2
Springs and Surface Water			
SP-5303	Southeast Drainage	63.8	1
SP-5304	Southeast Drainage	59.8	1
SP-6301	Burgermeister Spring Branch	47.9	4
SP-6303	Burgermeister Spring Branch	NS	0
SW-2007	Dardenne Creek	0.66	2

NS = not sampled

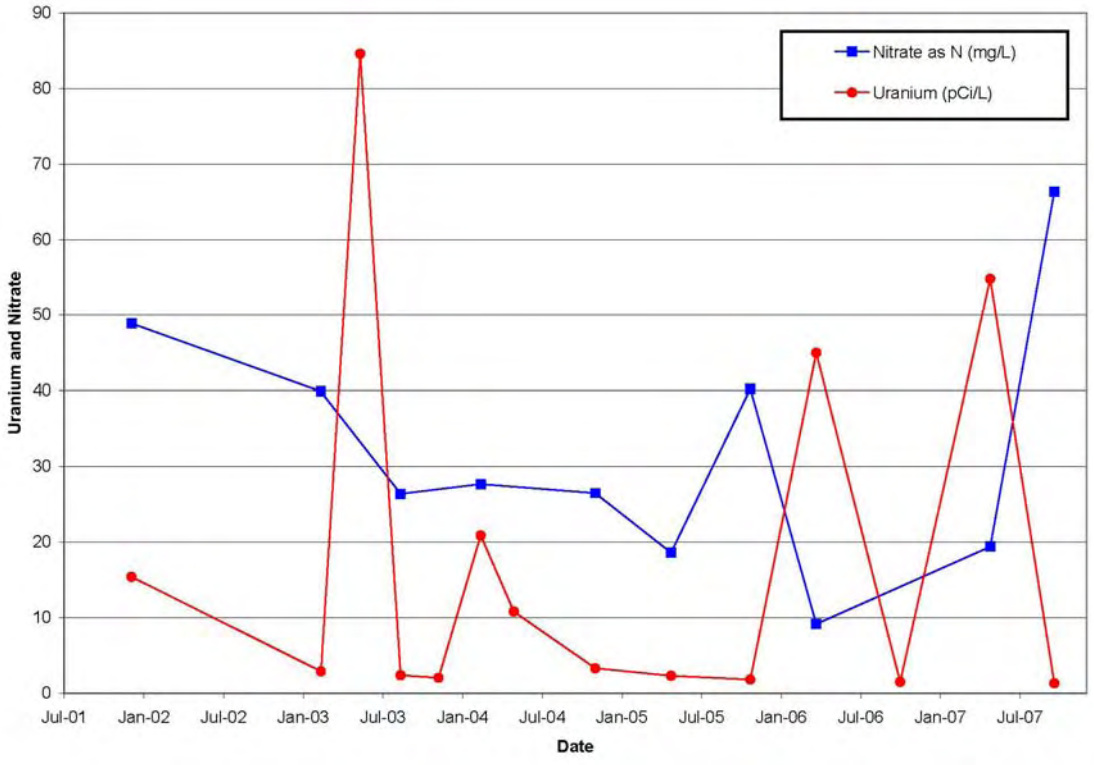

Figure 3–15. Uranium and Nitrate Levels in MW-4036 (2001−2007)

Review of the nitrate and uranium concentrations suggests a pattern. Starting in 2005, the uranium and nitrate values are inversely correlated. This pattern is similar to that seen historically in Burgermeister Spring and suggests a surface water component. Well MW-4036 is located adjacent to a stream channel that collected surface water from the former Raffinate Pits area. This stream segment is a losing segment with a known connection to Burgermeister Spring. No correlation was identified between contaminant concentrations and groundwater elevation or precipitation events.

Uranium levels in Burgermeister Spring (SP-6301) have increased since 2004 (Figure 3–16); however, the levels are significantly less than historical highs. The levels in 2007 in Burgermeister Spring ranged between 10 pCi/L and 74 pCi/L and are less than the trigger level (150 pCi/L) established for the spring. Analysis indicates no trend at Burgermeister Spring, based on data from the last 5 years. No samples were collected at SP-6303 during 2007 because the spring had no measurable flow; however, it should be noted that uranium levels have consistently been less than the MCL at this location.

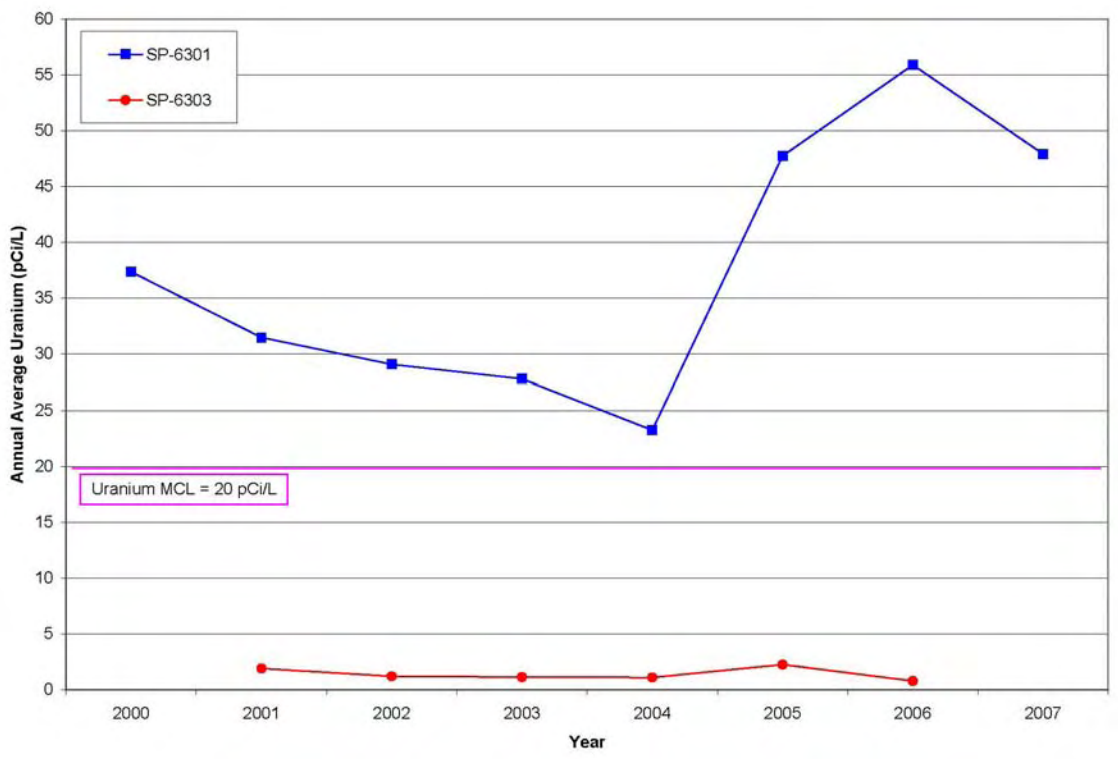

Figure 3–16. Annual Average Uranium Levels in Burgermeister Spring and SP-6303 (2000−2007)

The uranium levels in the two Southeast Drainage springs monitored under this program have fluctuated (Figure 3–17), and the behavior is similar in both springs. The levels in 2007 are similar to those observed in 2006. Uranium levels in both springs exceed the MCL but are less than the trigger level established for the springs. No trends have been identified in the data from the past 5 years. Only one sample was collected from the Southeast Drainage springs because there was no measureable flow during the second half of 2007. During 2007, uranium levels in MW-4026, a monitoring well downgradient of the two springs, were less than the detection limit.

The uranium levels in Dardenne Creek measured at location SW-2007 are similar to background. The levels measured during 2007 are similar to those measured during 2006.

Nitrate (as N)

The nitrate concentrations in the detection monitoring wells indicate that the movement of the area of impact is behaving as expected. No increases were observed in either the weathered or unweathered unit wells. Well MWS-1 continued to exceed the MCL for nitrate (as N) during both sampling events but was less than the trigger level (30 mg/L) set for this location. An estimated value (less than the detection limit of 1.0 µg/L) was reported for SP-6303. This is consistent with historical data. A summary of the data is presented in Table 3–13.

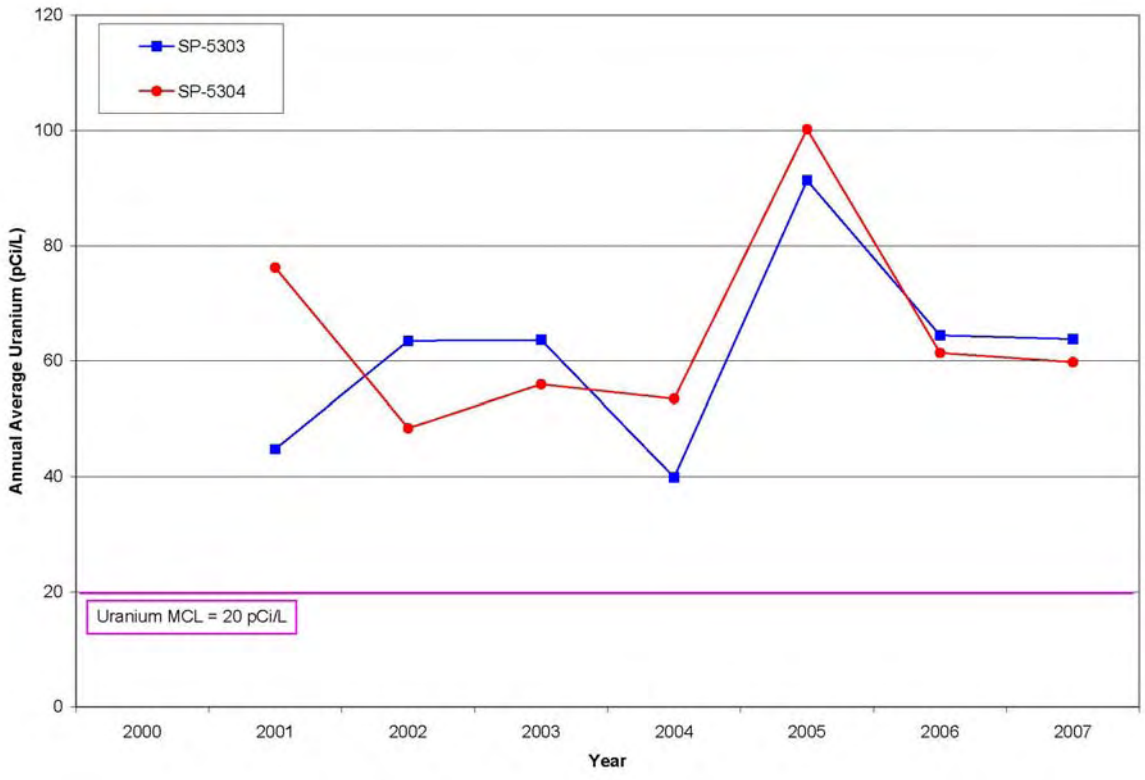

Figure 3–17. Annual Average Uranium Levels in Southeast Drainage Springs (2000−2007)

The nitrate concentrations in Burgermeister Spring ranged between 1.3 mg/L and 6.4 mg/L, which are less than the MCL of 10 mg/L. Nitrate concentrations in Burgermeister Spring have been less than the MCL since 2002 (Figure 3–18). The concentrations measured during 2007 are similar to those measured in 2006. Spring SP-6303 was not sampled during 2007 because there was no measurable flow.

Table 3–13. 2007 Nitrate (as N) Data for Objective 3, 4, and 5 Locations

Sample ID	Location	Average (mg/L)	Number of Samples
Weathered Unit			
MW-4014	Fringe	2.8	2
MW-4041	Downgradient	0.27	2
MWS-1	Downgradient	14.2	2
MWS-4	Downgradient	2.9	1
Unweathered Unit			
MW-2021	Vertical Extent	ND	2
MW-2022	Vertical Extent	ND	2
MW-3006	Fringe	ND	2
MW-4007	Downgradient	ND	2
MW-4042	Downgradient	ND	2
MWD-2	Downgradient	ND	3
Springs			
SP-6301	Burgermeister Spring Branch	4.2	4
SP-6303	Burgermeister Spring Branch	NS	0

ND = non-detect
NS = not sampled

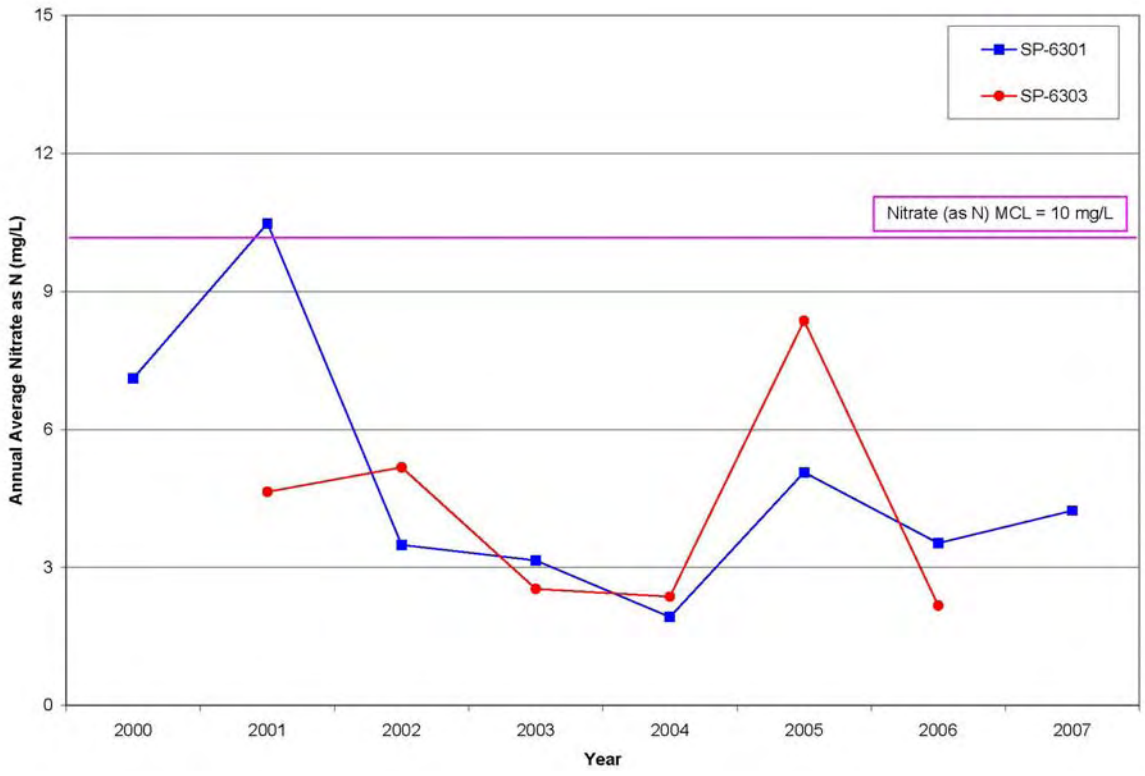

Figure 3–18. Annual Average Nitrate Concentrations in Burgermeister Spring and SP-6303 (2000−2007)

Trichloroethylene

TCE was not detected in the detection monitoring wells; however, estimated values (less than 1 mg/L) were reported at five locations. This indicates that the area of TCE impact has not expanded to a great extent, either laterally or vertically. Estimated values are concentrations reported less than the quantification limit and could indicate the presence of TCE. Subsequent data will continue to be evaluated. The trigger level of TCE is 15 mg/L in closer Objective 3 wells. No detectable concentrations of TCE were reported at Burgermeister Spring. A summary of the data is presented in Table 3–14.

Table 3–14. 2007 TCE Data for Objective 3, 4, and 5 Locations

Sample ID	Location	Average (µg/L)	Number of Samples
Weathered Unit			
MW-3031	Fringe	ND	2
MW-3037	Fringe	< 1 (a)	2
MW-4036	Downgradient	< 1 (a)	2
MW-4041	Downgradient	ND	2
MWS-1	Downgradient	< 1 (a)	2
MWS-4	Downgradient	< 1 (a)	2
Unweathered Unit			
MW-3006	Fringe	ND	2
MW-4007	Downgradient	ND	2
MW-4040	Vertical Extent	< 1 (a)	4
MW-4042	Downgradient	ND	2
Springs			
SP-6301	Burgermeister Spring Branch	ND	4
SP-6303	Burgermeister Spring Branch	NS	0

ND = non-detect
NS = not sampled
(a) estimated values reported

Nitroaromatic Compounds

The nitroaromatic compound concentrations in the detection monitoring wells indicate that the movement of the discrete areas of impact is behaving as expected. Concentrations of 2,6-DNT at MW-4015 and 2,4-DNT at MW-4036 observed during 2007 were slightly higher than those measured in 2006. However, concentrations of both analytes were within historical ranges. Otherwise, no increases were observed downgradient or laterally from either of the areas of impact in the weathered unit. None of these locations exceed the cleanup standards for the five compounds or the trigger levels set for these locations. The data for the unweathered unit wells were all reported as not detected. A summary of the data is presented in Table 3–15.

3.1.1.7 Trend Analysis

Concentrations of contaminants of concern are expected to decrease to cleanup standards within a reasonable timeframe (i.e., approximately 100 years). Long-term trend analysis is performed to confirm downward trends in contaminant concentrations over time. Performance of the remedy will be gauged against long-term trends of the Objective 2 wells for each contaminant of concern. It is anticipated that some locations may show temporary upward trends as a result of recent source removal and ongoing dispersion.

Table 3–15. 2007 Nitroaromatic Compound Data for Objective 3, 4, and 5 Locations

Sample ID	Location	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT	NB	Number of Samples
Weathered Unit							
MW-2032	Fringe	ND	ND	ND	ND	ND	2
MW-2051	Fringe	ND	0.10	0.07	ND	ND	2
MW-3037	Fringe	---	---	ND	---	---	2
MW-4013	Downgradient	---	---	ND	0.53	ND	2
MW-4014	Downgradient	ND	ND	ND	ND	ND	2
MW-4015	Downgradient	---	---	0.11	1.02	ND	2
MW-4036	Downgradient	---	---	0.09	---	---	2
MW-4039	Fringe	ND	ND	ND	ND	ND	2
MW-4041	Downgradient	ND	ND	ND	ND	ND	2
MWS-1	Downgradient	---	---	ND	---	---	2
Unweathered Unit							
MW-2022	Fringe	ND	ND	---	---	---	3
MW-2023	Vertical Extent	ND	ND	ND	ND	ND	3
MW-2056	Vertical Extent	ND	ND	ND	ND	ND	3
MW-3006	Fringe	---	---	ND	---	---	2
MW-4040	Vertical Extent	---	---	ND	---	---	4
MW-4042	Downgradient	ND	ND	ND	ND	ND	2
Springs							
SP-6301	Burgermeister Spring Branch	ND	ND	ND	0.10	ND	4
SP-6303	Burgermeister Spring Branch	NS	NS	NS	NS	NS	0

ND = non-detect
NS = not sampled
--- = These contaminants are not monitored at these locations.

As outlined in the *Remedial Design/Remedial Action Work Plan for the Final Remedial Action for the Groundwater Operable Unit at the Weldon Spring Site* (DOE 2004c), a trend method using the nonparametric Mann-Kendall test is used. The Mann-Kendall test is used for temporal trend identification because it can easily facilitate missing data and does not require the data to conform to a particular distribution (such as a normal or log-normal distribution). The nonparametric method is valid for scenarios where there are a high number of non-detect data points. Data reported as trace concentrations or less than the detection limit can be used by assigning them a common value that is smaller than the smallest measured value in the data set (i.e., one-half the specified detection limit). This approach is valid because only the relative

magnitudes of the data, rather than their measured values, are used in the method. A possible consequence of this approach is that the test can produce biased results, if a large fraction of data within a given time series are non-detect and if detection limits change between sampling events. One-half the specified detection limit (on the date of analysis) was used in place of all concentrations reported at or below the detection limit.

The two-tailed version of the Mann-Kendall test was employed to detect either an upward or downward trend for each data set. As part of this approach, a test statistic, Z, was calculated. A positive value of Z indicated that the data were skewed in an upward direction, and a negative value of Z indicated that the data were skewed in a downward direction. The alpha value (or error limit) used to identify a significant trend was 0.05. The null hypothesis of "no trend" was rejected if the absolute value of the Z statistic was greater than Z_1-$\alpha/_2$, where Z_1-$\alpha/_2$ was obtained from a cumulative normal distribution table. In other words, the absolute value of the output statistic, Z, was compared to the tabular $Z_{0.975}$ value of 1.96. If the absolute value of the Z output statistic was greater than 1.96, then a significant trend was reported.

A non-parametric estimate of the slope, which is calculated independently of the trend, was determined for each data set. In addition, a 95 percent (1-α) two-sided confidence interval about the true slope was obtained. The direction and magnitude of the slope, along with associated upper and lower 95 percent confidence limit estimates, are included in test results presented in the following section.

Testing for temporal trends was performed for the contaminants of concern for the GWOU using data collected between 2003 and 2007. Results for the trending analysis are reported for the Objective 2 wells and the Objective 5 springs because these locations monitor the area of groundwater impact and the discharge points.

Results for trend analyses for uranium (Table 3–16) indicate that the levels measured over the past 5 years are changing in the Objective 2 wells, except for in well MW-3040. Downward trends were determined for MW-3003 and MW-3030 (weathered wells) while upward trends were calculated for MW-3024 (weathered well) and MW-4040 (unweathered well). The upward trend in MW-3024 is changed from 2006 when no trend was calculated. Uranium levels in MW-3040 have been relatively stable over the past 5 years. The stabilization and decreases of the uranium levels is the result of source removal in the Raffinate Pits area. Increases are observed in wells that are close to the paleochannels. However, flushing of the system is slow due to the low amount of recharge through the system, so it is unlikely that changes will be rapid.

Table 3–16. Trending Analysis for Uranium in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Lower
MW-3003	12	Down	-2.64	-3.46	-1.76
MW-3024	13	Up	14.6	7.32	19.4
MW-3030	13	Down	-3.09	-4.68	-2.11
MW-3040	15	None	3.53	-2.03	6.86
MW-4040	15	Up	33.2	12.6	50.8

Some decreases have been indicated, based on the results of the trending analyses (Table 3–17). Wells MW-2040 and MW-3040 continued to exhibit downward trends during 2007. In 2006,

wells MW-4031 had a downward trend, which was not detected in this most recent trend analysis. No upward trends were calculated. Concentrations in wells MW-4031 and MW-4036 have been relatively stable over the past 5 years. Again, the stabilization of the concentrations is the result of source removal in the Raffinate Pits and Ash Pond areas and of limited recharge to the area.

Results of the trend analysis for the Objective 2 TCE wells indicate that concentrations in groundwater have become more variable (Table 3–18). No trends were calculated from the data collected from 2003 through 2007. Trend analysis performed in 2006 indicated an upward trend in TCE concentrations in well MW-3030, but no trend was evident from this most recent analysis of the data.

Table 3–17. Trending Analysis for Nitrate (as N) in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (mg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-2038	10	None	0.82	-53.1	54.1
MW-2040	10	Down	-12.4	-30.7	-0.28
MW-3003	11	None	38.4	-18.6	140
MW-3034	9	None	-79.5	-207	61.3
MW-3040	14	Down	-31.6	-42.3	-25.6
MW-4013	9	None	-3.05	-30.2	4.93
MW-4029	10	None	26.7	-16.2	92.0
MW-4031	10	None	-11.2	-22.3	12.9
MW-4036	9	None	-1.76	-9.65	10.0
MW-4040	15	None	-2.33	-21.8	16.1

Table 3–18. Trending Analysis for TCE in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-3030	11	None	-6.77	-36.5	63.2
MW-3034	14	None	0	-91.5	81.0
MW-4029	14	None	-1.88	-33.1	50.0

Results of the trend analyses for the nitroaromatic compounds (Table 3–19 through Table 3–22) indicated upward trends in the Frog Pond area for 2,4-DNT, and 2,6-DNT in wells MW-2050 and MW-2053. Decreasing trends in 2,4-DNT were determined for MW-2054 and MW-3039 in the Raffinate Pits area. Downward trends were calculated for all of the nitroaromatic compound data from MW-2012; however, it is suspected that the recent decreases (since 2004) observed in nitroaromatic compounds at this location are the result of surface infiltration. Downward trends associated with MW-2012 are not considered to be the result of attenuation processes (DOE 2006b). A review of the trend data suggests that concentrations of both 2,4-DNT and 2,6-DNT are relatively stable in those wells where slopes and confidence intervals are small.

Table 3–19. Trending Analysis for 2,4-DNT in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-2012	15	Down	-320	-436	-232
MW-2014	13	None	0	-0.03	0.05
MW-2038	11	None	-0.01	-0.08	0.10
MW-2050	13	None	0	-2.63	3.67
MW-2052	11	None	0	-0.02	0.004
MW-2053	10	Up	0.08	0	0.18
MW-2054	13	Down	-0.76	-2.87	0
MW-3030	13	None	-0.04	-0.10	0.01
MW-3034	11	None	-0.04	-0.12	0.01
MW-3039	13	None	-0.26	-0.38	0.06

Table 3–20. Trending Analysis for 2,6-DNT in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-2012	15	Down	-267	-328	-198
MW-2014	13	None	-0.03	-0.09	0.17
MW-2050	13	Up	9.20	7.89	11.3
MW-2052	13	None	0.02	-0.07	0.17
MW-2053	13	Up	0.74	0.19	1.63
MW-2054	13	None	-2.32	-11.3	3.37

Table 3–21. Trending Analysis for 2,4,6-TNT in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-2012	14	Down	-85.2	-100	-58.0
MW-2046	9	None	-0.05	-2.01	1.72
MW-2053	12	None	-1.08	-3.53	1.33

Table 3–22. Trending Analysis for 1,3-DNB in Objective 2 MNA Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-2012	13	Down	-0.78	-1.35	-0.31

Testing for temporal trends was performed on the uranium data from the Objective 5 springs (Table 3–23). Results of the analysis indicated no trend in the data from the past 5 years. A review of the data suggests that uranium levels have been stable in SP-6303.

Table 3–23. Trending Analysis for Uranium in Objective 5 MNA Springs

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Lower
SP-5303	19	None	2.92	-9.94	13.8
SP-5304	24	None	4.00	-5.73	17.8
SP-6301	25	None	6.91	-0.08	14.3
SP-6303	23	None	-0.02	-0.40	0.44

3.1.1.8 Hydrogeologic Data Analysis

Site hydrogeologic conditions over time are being monitored using all the wells included in the MNA network (Objective 1, 2, 3, and 4 wells) and additional wells (Objective 6 wells) that were selected to provide adequate coverage in order to identify changes in groundwater flow that might affect the protectiveness of the selected remedy. The static groundwater elevations of the monitoring network are measured to establish that groundwater flow is not changing significantly and resulting in shifts in contaminant migration.

The average groundwater elevations were used to construct a potentiometric surface map of the shallow aquifer using the available wells at the Chemical Plant (Figure 3–19). The configuration of the potentiometric surface has remained relatively unchanged. However, groundwater elevations have decreased in several portions of the Site. Even though changes have occurred in the groundwater elevations, the groundwater flow direction continues to be generally to the north. A groundwater divide is present along the southern boundary of the Chemical Plant Site.

Groundwater elevations have shown a general decrease in the Raffinate Pits area in wells screened in the weathered and unweathered units of the Burlington-Keokuk Limestone (Figure 3–20 through Figure 3–21). Trend analysis of groundwater-elevation data collected since 2000 indicates that elevations have decreased in 27 of 39 of the wells screened in the weathered unit and 3 out of 5 wells screened in the unweathered unit. Decreases range from 0.07 ft per year to 0.52 ft per year. The largest decreases were observed in the unweathered-unit wells.

Decreases in groundwater elevations have occurred to a lesser extent in the Frog Pond and Ash Pond areas (Figure 3–22 through Figure 3–23). Downward trends are present in wells screened in both the weathered and unweathered units. Decreases occurred in 6 out of 18 wells in the Ash Pond area and 4 out of 10 wells in the Frog Pond area.

3.1.1.9 Recommendations – GWOU Monitoring Program

The concentrations of the upgradient (Objective 1) wells have been relatively stable. These wells have been sampled semiannually. It is recommended to reduce the sampling frequency to annual starting in 2008.

The majority of the contaminant data trends in the Objective 2 wells have been stable, though variable data have been reported primarily in the former Raffinate Pits area. The sampling frequency for the Objective 2 wells has been semiannual. Due to variable data that are still reported for some locations, semiannual sampling should be retained for the Objective 2 wells. However, the two Objective 2 unweathered wells will be kept on a quarterly sampling frequency for at least 2 more years (2009).

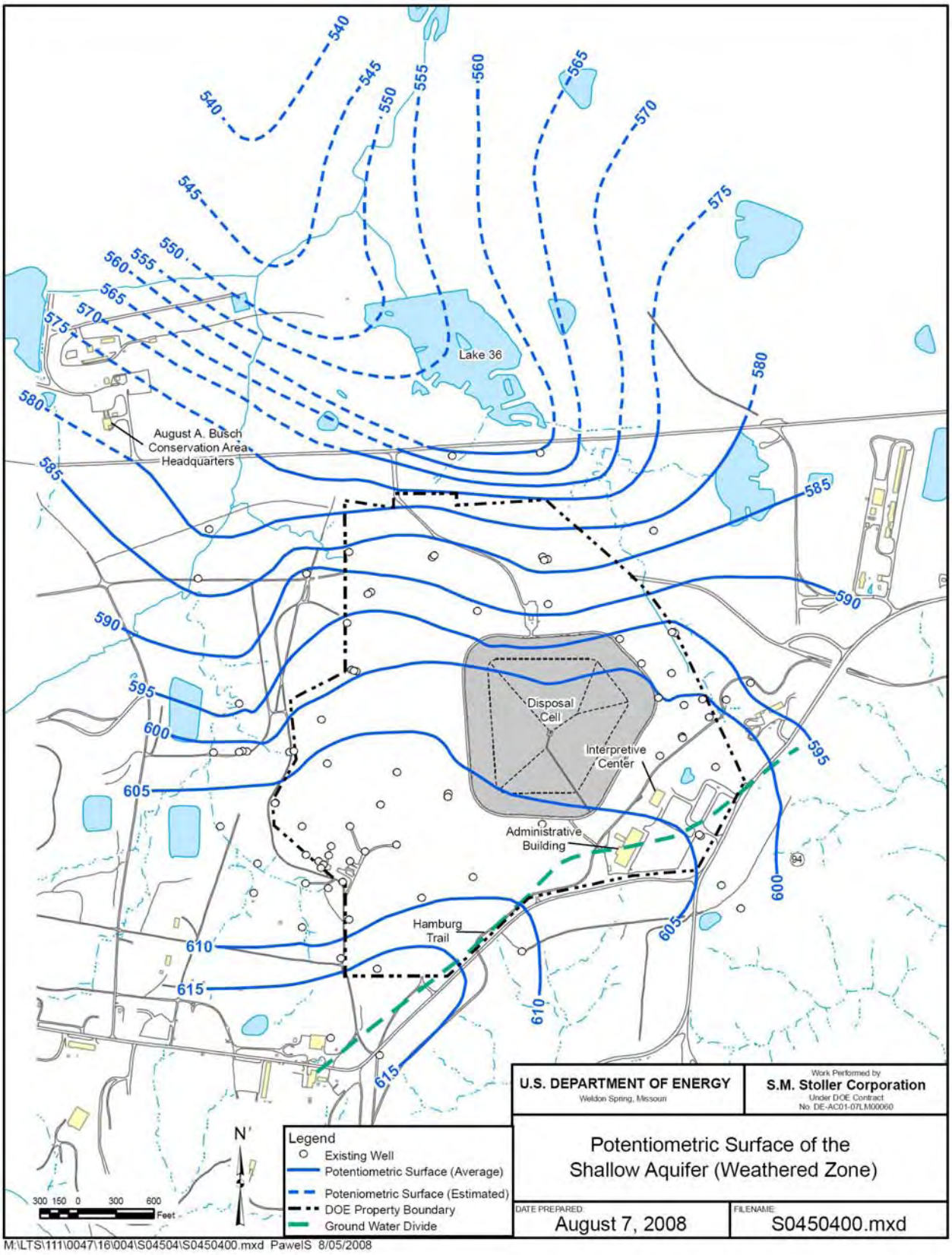

Figure 3–19. Potentiometric Surface of the Shallow Aquifer (Weathered Zone)

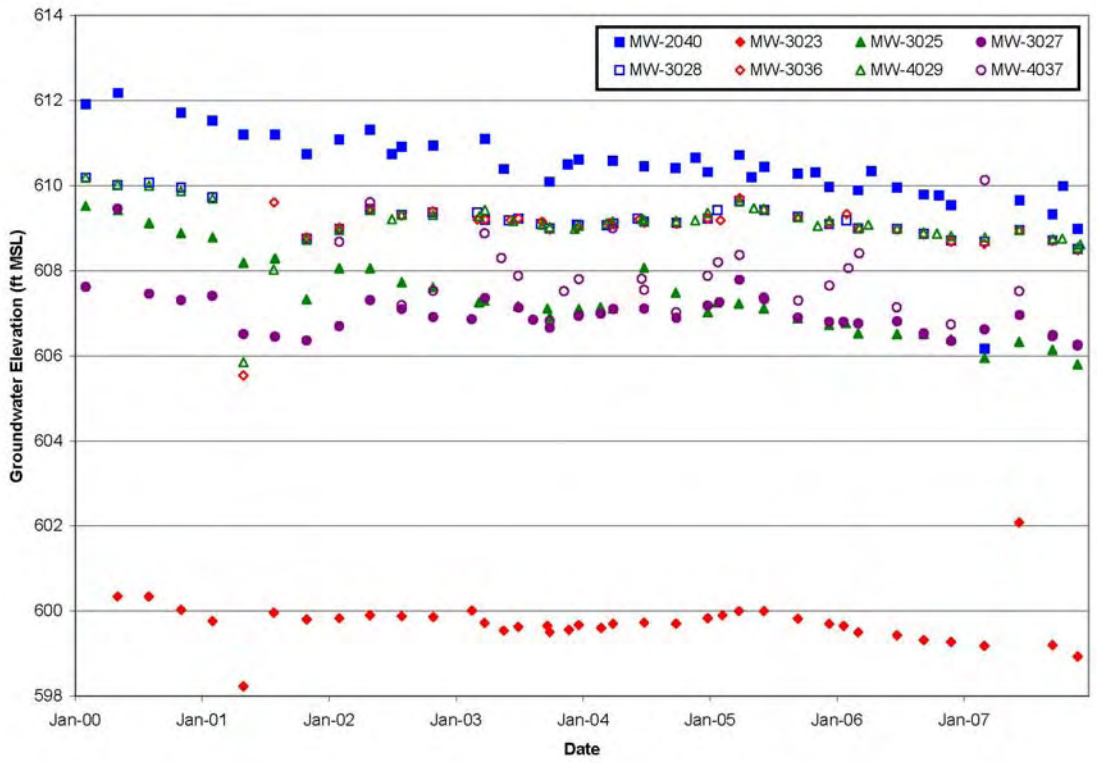

Figure 3–20. Groundwater Elevations in Raffinate Pits Area – Weathered Wells

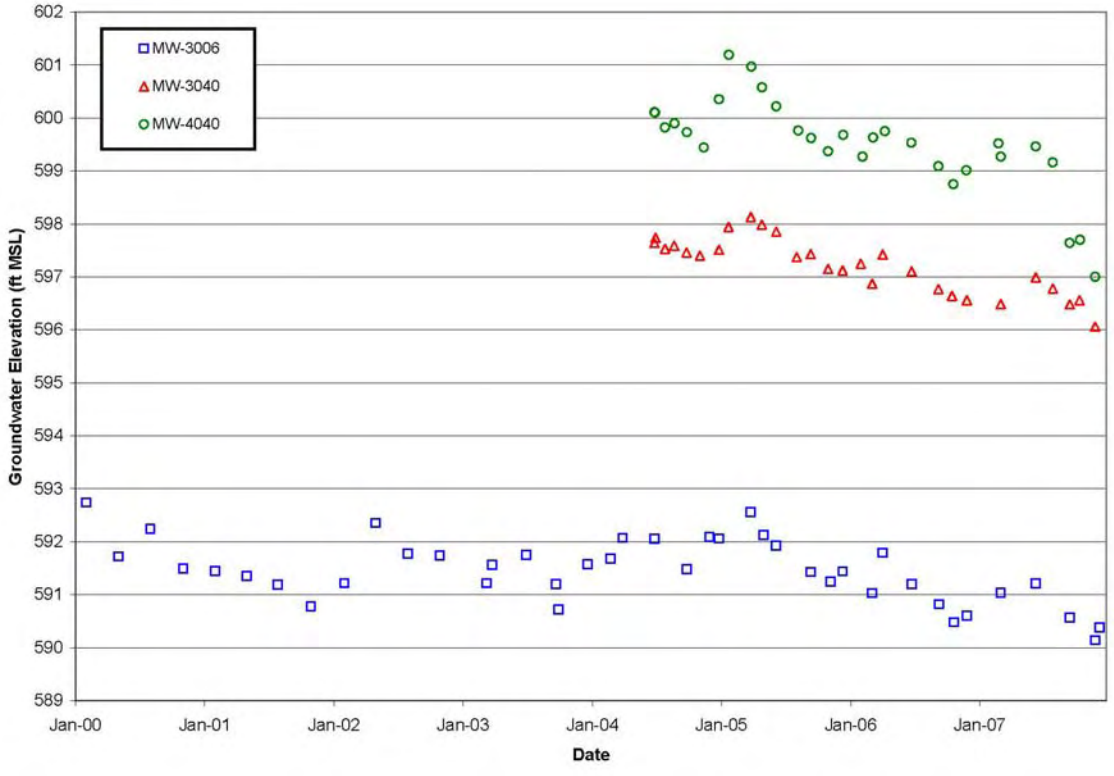

Figure 3–21. Groundwater Elevations in Raffinate Pits Area – Unweathered Wells

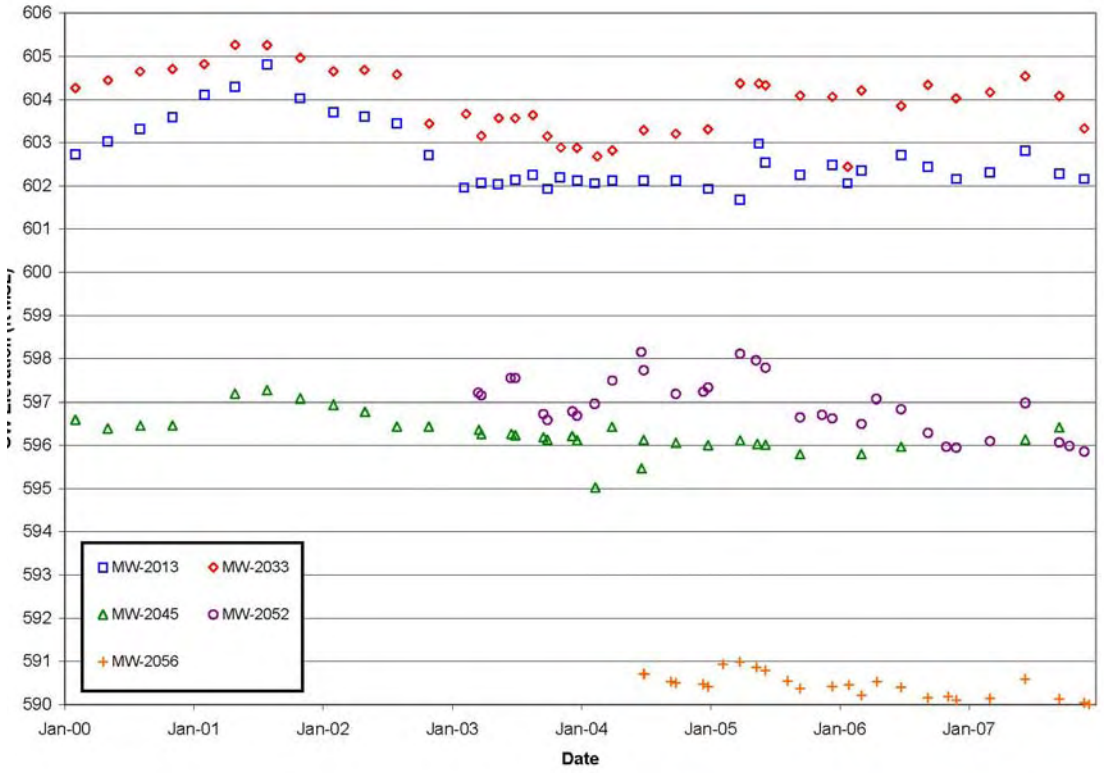

Figure 3–22. Groundwater Elevations in Frog Pond Area

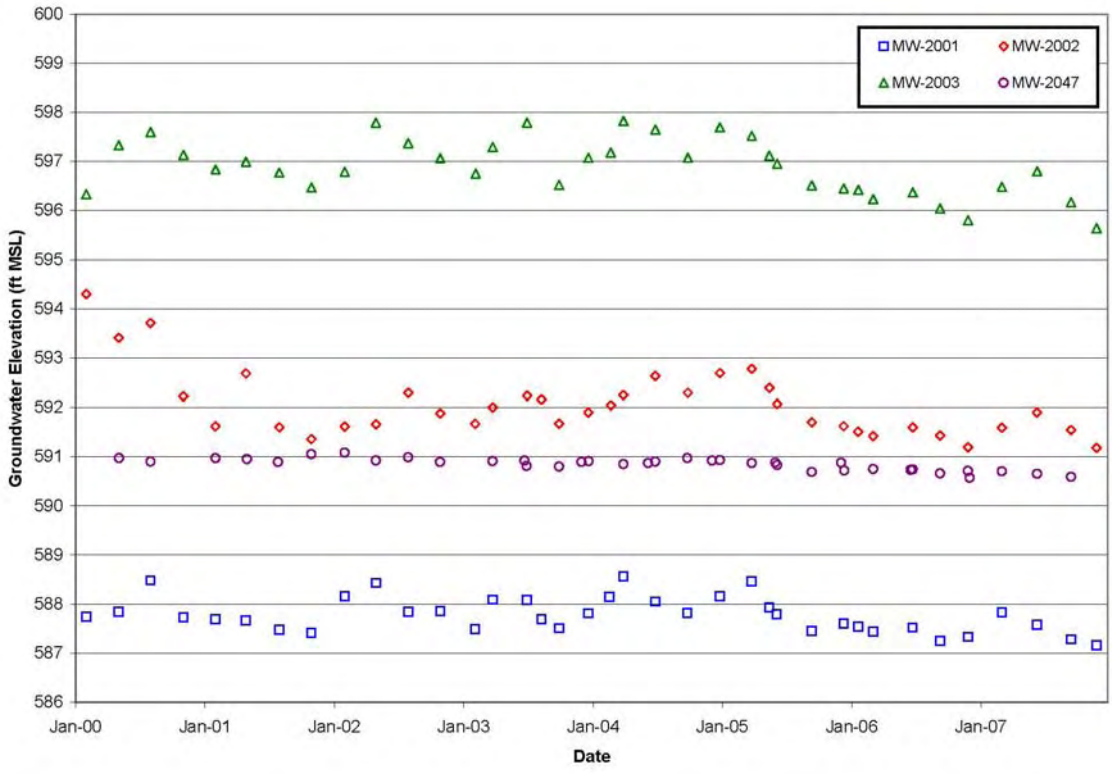

Figure 3–23. Groundwater Elevations in Ash Pond Area

Concentrations in downgradient (laterally and vertically) and fringe locations (Objective 3) have been behaving as expected; however, uranium levels in well MW-4036 are higher than predicted. These locations have been sampled semiannually. It is recommended to reduce the sampling frequency to annual for the wells sampled for nitrate, TCE, and nitroaromatic. However, the Objective 3 wells associated with uranium should remain on a semiannual sampling frequency in response to the changes observed in Raffinate Pits area. Also, MW-4036 will be sampled quarterly for uranium and nitrate during 2008.

The majority of the contaminant data trends in the springs (Objective 5) have been stable over time; however, variable uranium data have been reported at Burgermeister Spring. The sampling frequency for the springs has been at least semiannual. Because of the variable data that are still reported for Burgermeister Spring and the changes in uranium that have been observed in the Raffinate Pits area, it is recommended to increase the sampling frequency to quarterly during 2008.

These recommendations have been incorporated into the LTS&M Plan (DOE 2005a) for the site. It is anticipated that this document will be finalized in October 2008 and the changes implemented in calendar year 2009.

3.1.2 Weldon Spring Quarry

EPA signed the QROU ROD (DOE 1998) on September 30, 1998. The QROU ROD specified long-term groundwater monitoring and ICs to limit groundwater use during the monitoring period. Groundwater north of the Femme Osage Slough will be monitored until a target level of 300 pCi/L is attained. In addition, groundwater south of the slough will be monitored to ensure protection of human health and the environment.

In 2000, DOE initiated a long-term monitoring program as outlined in the *Remedial Design/Remedial Action Work Plan for the Quarry Residuals Operable Unit* (DOE 2000). This network was modified to add wells upgradient of the Quarry (MW-1012), downgradient of the area of impact (MW-1028), and within the area of highest uranium impact (MW-1051 and MW-1052).

3.1.2.1 Hydrogeologic Description

The geology of the Quarry area is separated into three units: upland overburden, Missouri River alluvium, and bedrock. The unconsolidated upland material overlying the bedrock consists of up to 30 ft of silty clay soil and loess deposits, and is not saturated (DOE 1989). Three Ordovician-age formations constitute the bedrock: the Kimmswick Limestone, the limestone and shale of the Decorah Group, and the Plattin Limestone. The alluvium associated with the Missouri River consists of clays, silts, sands, and gravels above the bedrock. The alluvium thickness increases with distance from the edge of the river floodplain toward the river, where the maximum thickness is approximately 100 ft.

Alluvium at the Quarry is truncated by an erosional contact with the Ordovician bedrock bluff consisting of Kimmswick, Decorah, and Plattin formations. These formations also form the rim wall of the Quarry. The bedrock unit underlying alluvial materials north of Femme Osage Slough is the Decorah Group. Primary sediments between the bluff and the slough are intermixed and inter-layered clays, silts, and sands. Organic material is intermixed throughout the sediments.

The area between the bedrock bluff and the Femme Osage Slough contains a naturally occurring oxidation/reduction front, which acts as a barrier to the migration of dissolved uranium in groundwater by inducing its precipitation. This reducing zone has been determined to be the primary mechanism controlling the distribution south of the Quarry.

The uppermost groundwater flow systems at the Quarry are composed of alluvial and bedrock aquifers. Water levels in the alluvial aquifer are primarily controlled by surface water levels in the Missouri River, and infiltration of precipitation and overland runoff that recharges the bedrock aquifer.

Eight groundwater monitoring wells in the Darst Bottom area, located approximately 1 mile southwest of the former St. Charles County well field, were utilized to study the water quality of the Missouri River alluvium upgradient of the Quarry. Data collected from them during the remedial investigation phase by both the U.S. Geological Survey (USGS) (1992) and DOE (1994) provided a reference for background values of uranium in the well field area. A summary of the resulting uranium background values is provided in Table 3–24 (DOE 1998a).

Table 3–24. Background Uranium Levels for Aquifer Units at the Quarry

Unit	Uranium (pCi/L)	
	Background Value (UCL95)[d]	Background Range
Alluvium[a]	2.77 pCi/L	0.1−16
Kimmswick/Decorah[b]	3.41 pCi/L	0.5−8.5
Plattin[c]	3.78 pCi/L[e]	1.2−5.1

[a]Based on data from Darst Bottom wells (USGS and DOE)
[b]Based on data from MW-1034 and MW-1043 (DOE)
[c]Based on data from MW-1042 (DOE)
[d]UCL95 = 95th percentile upper confidence limit on the mean concentration
[e]This background value is lower than previously published as a result of recent data evaluation.

3.1.2.2 Contaminants of Interest

Uranium and nitroaromatic compounds leached from the wastes in the Quarry proper and contaminated groundwater beneath and downgradient of the Quarry. Contaminant levels have decreased since the removal of the wastes from the Quarry. The remaining source of groundwater contamination is residual material in the fractures and uranium that has precipitated or sorbed in the alluvial materials north of the Femme Osage Slough.

Uranium entered the shallow aquifer via migration through the bedrock fractures in the Kimmswick Limestone and Decorah Formation that constitute the Quarry. The extent of uranium in groundwater was limited to the area north of the slough by precipitation by a naturally occurring chemical-reduction process and adsorption onto aquifer materials.

Nitroaromatic compounds, primarily 2,4-DNT in the groundwater system coincide with where these wastes were disposed of in the Quarry proper. Nitroaromatic compounds entered the shallow aquifer via migration through the bedrock fractures of the Quarry. The mobility of nitroaromatic compounds in the bedrock aquifer is high due to little sorption to the bedrock

materials. Some microorganism activity may be able to transform and degrade TNT and DNT in the alluvial materials north of the slough.

3.1.2.3 Quarry Monitoring Program

Long-term monitoring at the Quarry is designed to (1) monitor uranium concentrations south of the slough to ensure that they remain protective of human health and the environment, and (2) monitor uranium and 2,4-DNT levels within the area of groundwater impact north of the slough until they attain target levels that have been identified as having a negligible impact on the groundwater south of the slough (DOE 2000a).

In order to implement these two monitoring objectives the wells were categorized into monitoring lines (Figure 3–24). Each line provides specific information relevant to long-term goals at the Quarry:

- The first line of wells (Line 1) monitors the area of impact within the bedrock rim of the Quarry proper. These wells (MW-1002, MW-1004, MW-1005, MW-1027, and MW-1030) are sampled to establish trends in contaminant concentrations within areas of higher impact.
- The second line of wells monitors the area of impact within alluvial materials and shallow bedrock north of Femme Osage Slough (MW-1006, MW-1007, MW-1008, MW-1009, MW-1013, MW-1014, MW-1015, MW-1016, MW-1028, MW-1031, MW-1032, MW-1045, MW-1046, MW-1047, MW-1048, MW-1049, MW-1051, and MW-1052). These wells are also sampled to establish trends in contaminant concentrations within the areas of higher impact and to monitor the oxidizing and reducing environments that are present within this area.
- The third line of wells monitors the alluvium found directly south of the slough. These wells (MW-1017, MW-1018, MW-1019, MW-1021, MW-1044, and MW-1050) have shown no impact from Quarry contaminants and are monitored as the first line of warning for potential migration of uranium south of the slough.
- The fourth line of wells monitors the same portion of the alluvial aquifer that supplies the Public Water Supply District #2 (formerly St. Charles County) well field. These wells (RMW-1, RMW-2, RMW-3, and RMW-4) are sampled to monitor the groundwater quality of the productive portions of the alluvial aquifer and to detect potential occurrences of uranium outside the range of natural variation.

Monitoring well MW-1012 has been retained as a background location for the Quarry proper. This well is screened in the Kimmswick Limestone and Decorah Group and is included with the Line 1 wells.

The sampling frequency for each location was selected to provide adequate reaction time on the basis of travel times from the residual sources and areas of impact to potential receptors. Monitoring wells on the Quarry rim and in the areas of highest impact are sampled quarterly. Locations south of the slough are sampled semiannually or annually. In 2007, all locations in the Quarry area were sampled for uranium, sulfate, and iron. A selected group of wells north of the slough were sampled for nitroaromatic compounds.

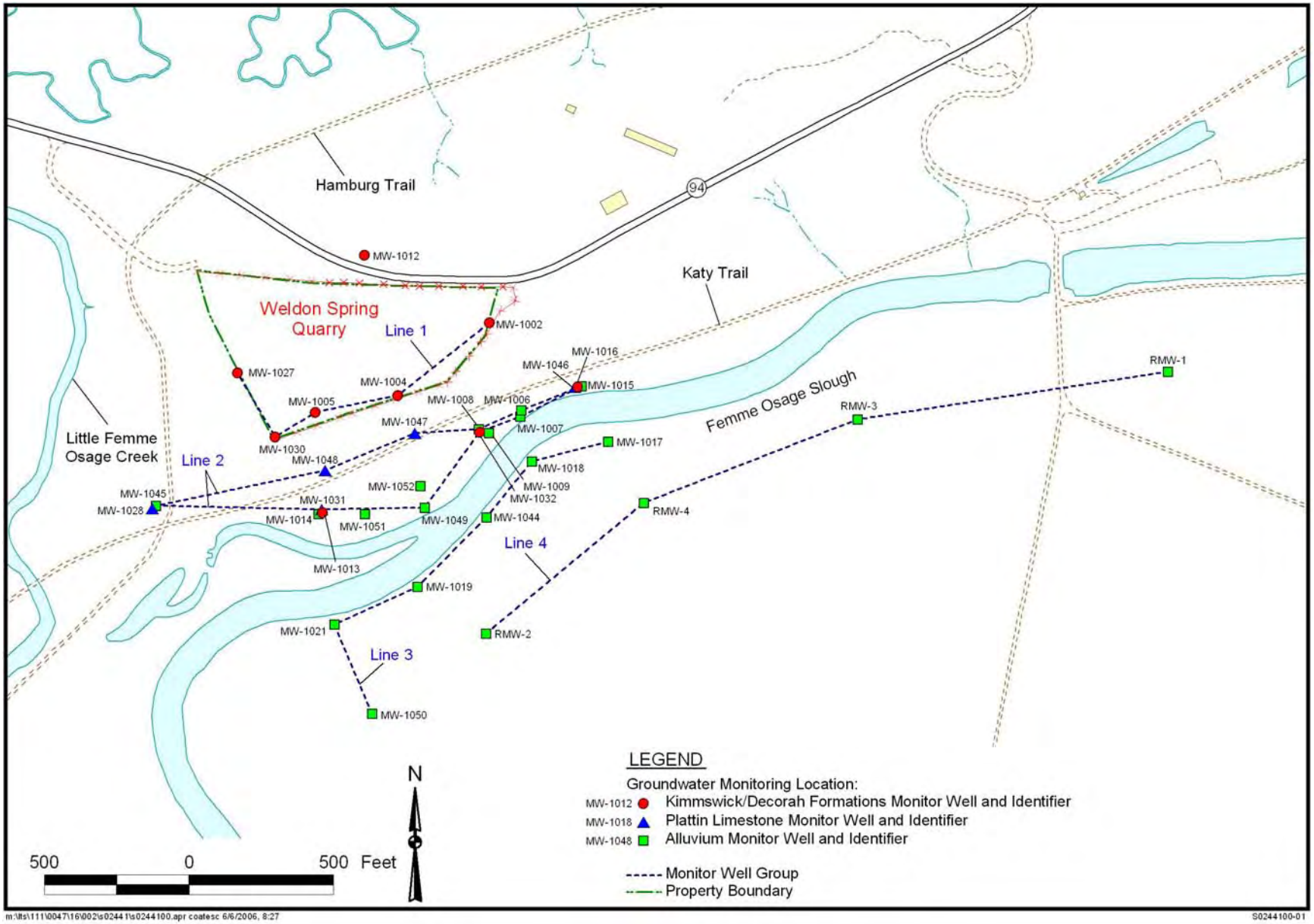

Figure 3–24. Groundwater Monitoring Well Locations at the Quarry Area of the Weldon Spring, Missouri, Site

3.1.2.4 Monitoring Results for Groundwater Within the Area of Impact at the Quarry

Contaminant concentrations are monitored using 24 wells screened in either the bedrock or alluvial materials in the area of uranium and 2,4-DNT impact, which is north of the Femme Osage Slough. The data is discussed in the following sections.

Uranium

Uranium values continue to indicate that the highest levels of uranium occur in bedrock and alluvial materials between the Quarry rim and Femme Osage Slough. The 2007 annual averages for total uranium are summarized in Table 3–25. Fourteen locations north of the slough exceed applicable maximum background levels for uranium listed in Table 3–24. Eleven of these locations exceed the target level of 300 pCi/L.

Table 3–25. Average Total Uranium (pCi/L) at the Weldon Spring Quarry During 2007

Location	Line	Geologic Unit	Average Concentration (pCi/L)	Number of Samples
MW-1002	1	Kimmswick-Decorah	3.7	4
MW-1004	1	Kimmswick-Decorah	**788**	4
MW-1005	1	Kimmswick-Decorah	**556**	4
MW-1012	1[a]	Kimmswick-Decorah	1.8	4
MW-1027	1	Kimmswick-Decorah	176	4
MW-1030	1	Kimmswick-Decorah	5.4	4
MW-1006	2	Alluvium	**1337**	4
MW-1007	2	Alluvium	**1872**	4
MW-1008	2	Alluvium	**3486**	4
MW-1009	2	Alluvium	3.2	4
MW-1013	2	Kimmswick-Decorah	286	4
MW-1014	2	Alluvium	**802**	4
MW-1015	2	Kimmswick-Decorah	134	4
MW-1016	2	Alluvium	100	4
MW-1028	2	Plattin	1.8	2
MW-1031	2	Plattin	11.4	4
MW-1032	2	Kimmswick-Decorah	**838**	4
MW-1045	2	Alluvium	6.2	4
MW-1046	2	Plattin	2.2	4
MW-1047	2	Plattin	0.93	4
MW-1048	2	Plattin	**320**	4
MW-1049	2	Alluvium	0.14	4
MW-1051	2	Alluvium	**688**	4
MW-1052	2	Alluvium	**333**	4

[a]Upgradient location.
Concentrations in bold = annual average exceeds target level of 300 pCi/L

Uranium levels in the Line 1 wells have shown a general decrease (Figure 3–25) as supported by trend analysis (Section 3.1.2.6). The levels in 2007 are similar to those measured during 2006. The average level of uranium in MW-1002, MW-1027, and MW-1030 are less than the target level of 300 pCi/L established for groundwater north of the Femme Osage Slough. Uranium

levels in MW-1002 and MW-1030 have consistently been less than the MCL of 20 pCi/L since 2001.

Uranium levels in alluvial wells within Line 2 continue to fluctuate; however, the levels in the bedrock wells have generally decreased since 2000 (Figure 3–26 and Figure 3–27). Alluvial wells MW-1007 and MW-1008 had significant increases during 2007 and had the greatest annual averages of all the wells in Line 2. Uranium levels in this area are correlated to the groundwater elevation, increasing if water levels increase substantially. It should be noted that the increases in annual averages observed in several of the wells during 2007 are exaggerated due to the substantial decrease in uranium levels reported in 2006. The 2006 decrease in uranium levels in 2006 was the result of lower than normal groundwater elevations in the Quarry area. Overall decreases, especially in the Line 2 bedrock wells, may also be attributed to decreases in uranium in the upgradient rim wells. The average levels of uranium in MW-1009, MW-1013, MW-1015, MW-1016, MW-1028, MW-1031, MW-1045, MW-1046, MW-1047, and MW-1049 are less than the target level of 300 pCi/L.

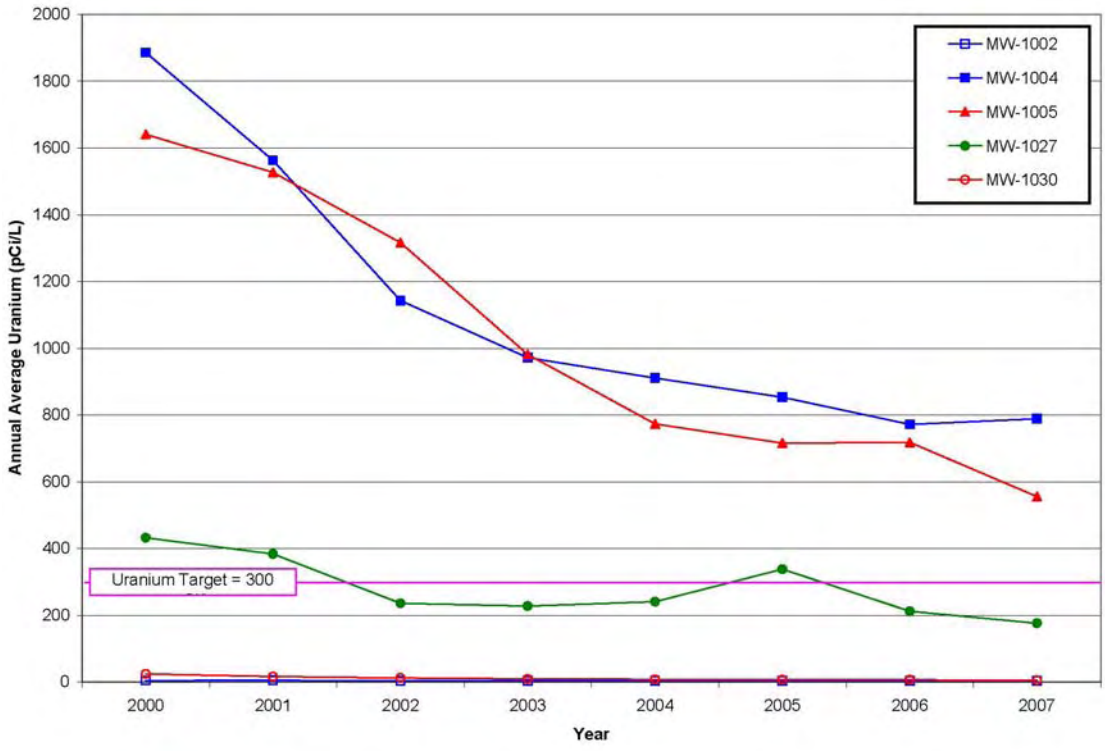

Figure 3–25. Average Uranium (pCi/L) in Line 1 Monitoring Wells

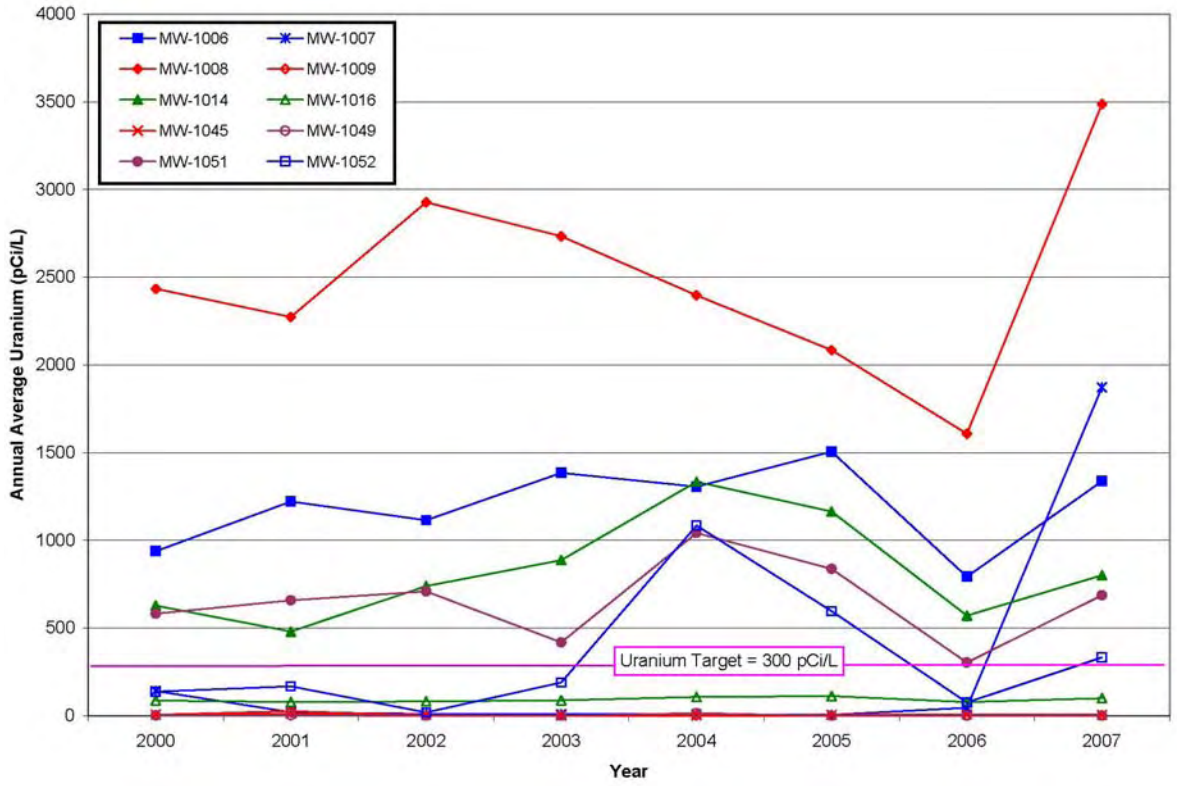

Figure 3–26. Average Uranium (pCi/L) in Line 2 Alluvial Wells

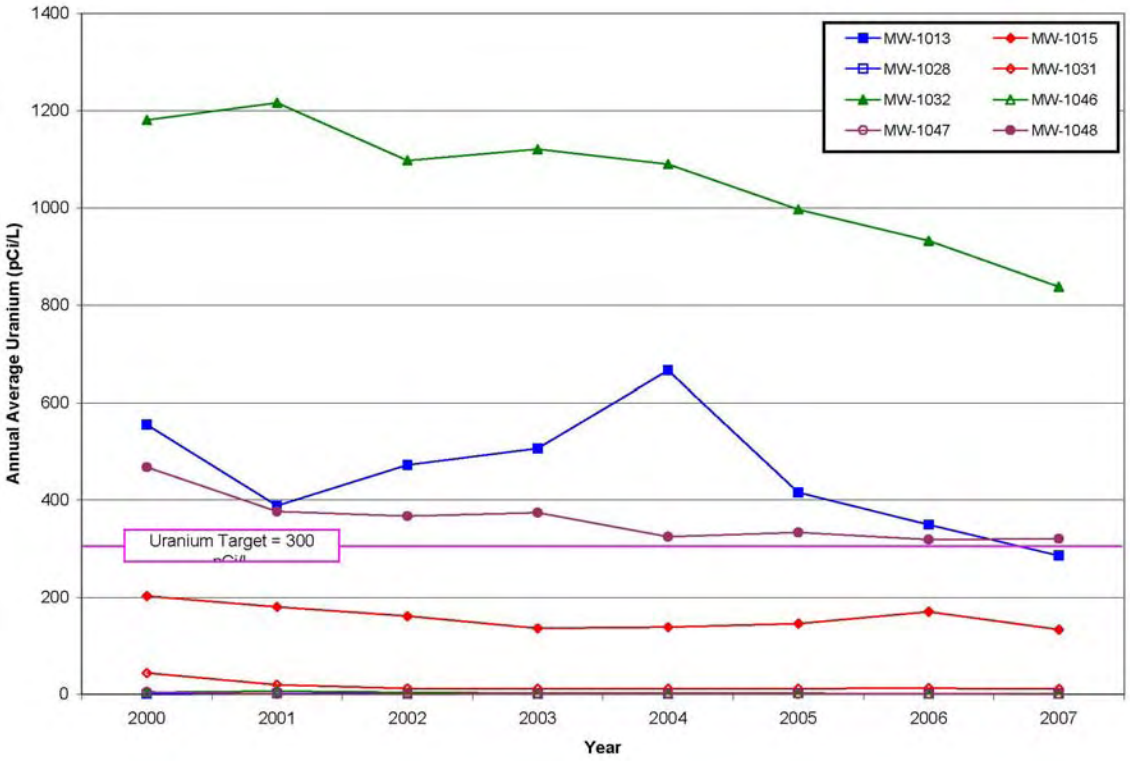

Figure 3–27. Average Uranium (pCi/L) in Line 2 Bedrock Wells

Well MW-1007 has historically shown little uranium impact because the well is screened within the reducing portion of the groundwater north of the slough. This well is paired with MW-1006, which is screened in the overlying oxidizing portion of the groundwater and has higher uranium levels (Figure 3–28). Well MW-1006 exhibits the pattern of increasing and decreasing uranium when the groundwater levels change. Generally well MW-1007 has shown little change with respect to groundwater levels as the reducing conditions are prevalent. The uranium levels reported in 2007 do not correlate with the geochemical data from this well. Increased groundwater elevations were reported in this area during 2007 after an extended period of low water level. This condition may have resulted in creating an oxidized condition in this area. Although elevated uranium levels have been reported along the northern boundary for the reduction zone, Line 3 data (Section 1.1.2.5) indicates no migration of uranium south of the Femme Osage Slough. Subsequent data will be evaluated.

Well MW-1008 has historically shown elevated levels of uranium (Figure 3–29). This well is screened in the shallow, oxidizing portion of the groundwater north of the slough. The uranium value of 5815 pCi/L reported during May 2007 is a recent high. A value of 5057 pCi/L was reported during 2003. This increased uranium value is the result of increases in the groundwater elevations in the area north of the slough. An increase in uranium levels with increased groundwater elevation is typical in this area of the Quarry. Well MW-1009 is nested with MW-1008, and uranium levels and groundwater elevations for this well are included to illustrate the lack of change in the well screened in the reducing portion of the groundwater system.

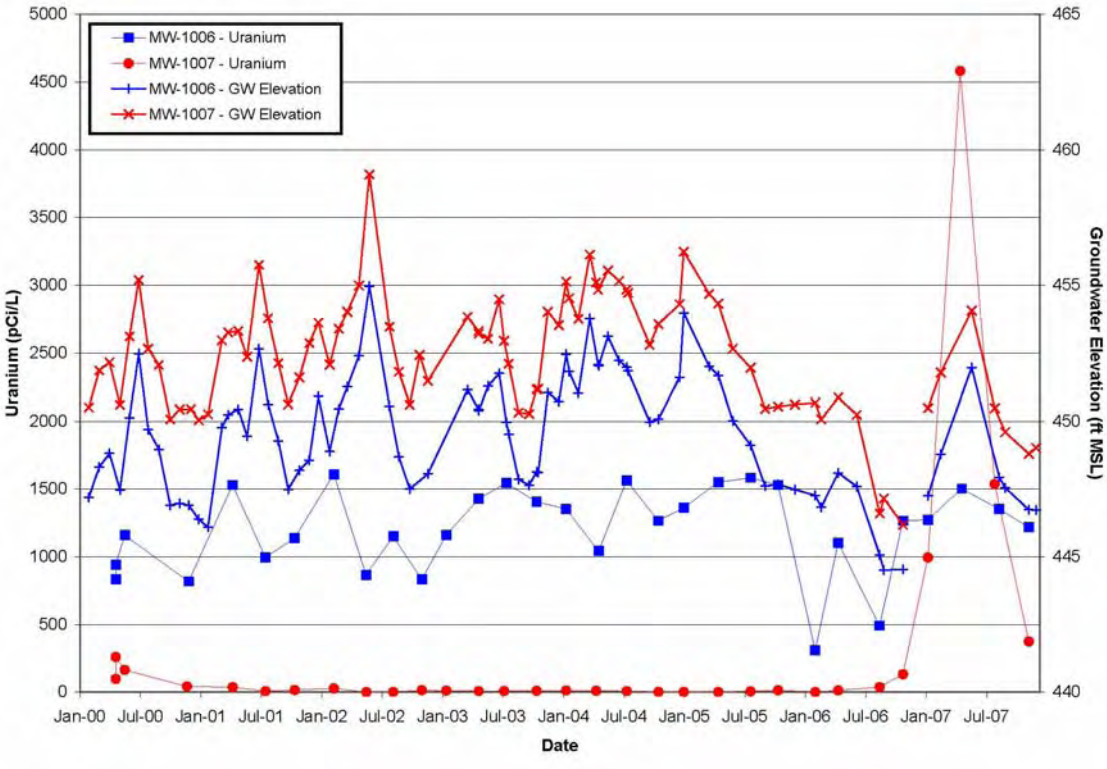

Figure 3–28. Uranium Levels and Groundwater Elevations in MW-1006 and MW-1007

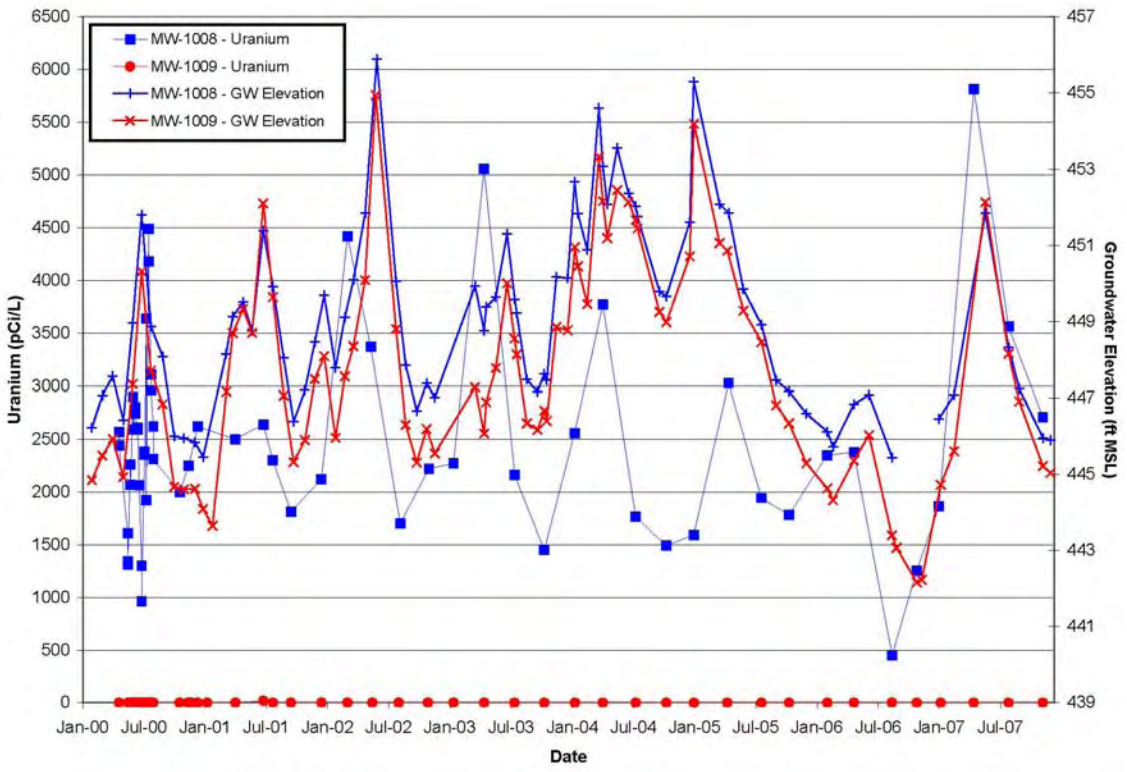

Figure 3–29. Uranium Levels and Groundwater Elevations in MW-1008 and MW-1009

The attainment objective for the long-term monitoring of uranium in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 300 pCi/L (DOE 2000a). Eleven wells north of the slough exceeded the target level in 2007. The 90th percentile associated with the data from the Line 1 and 2 wells was 1,361 pCi/L. This value is considerably higher than pervious years (Figure 3–30). The decrease is 2006 was due to the lower-than-typical water levels in this area. Looking at the 90th percentile for each line (1 and 2) separately indicates that the increased metric was the result of changes in uranium levels in the Line 2 wells. In general, the levels in Line 1 have been stable compared to those in Line 2. Higher uranium levels have been correlated to higher water levels. Uranium monitoring will continue in 2008, and subsequent data will be evaluated.

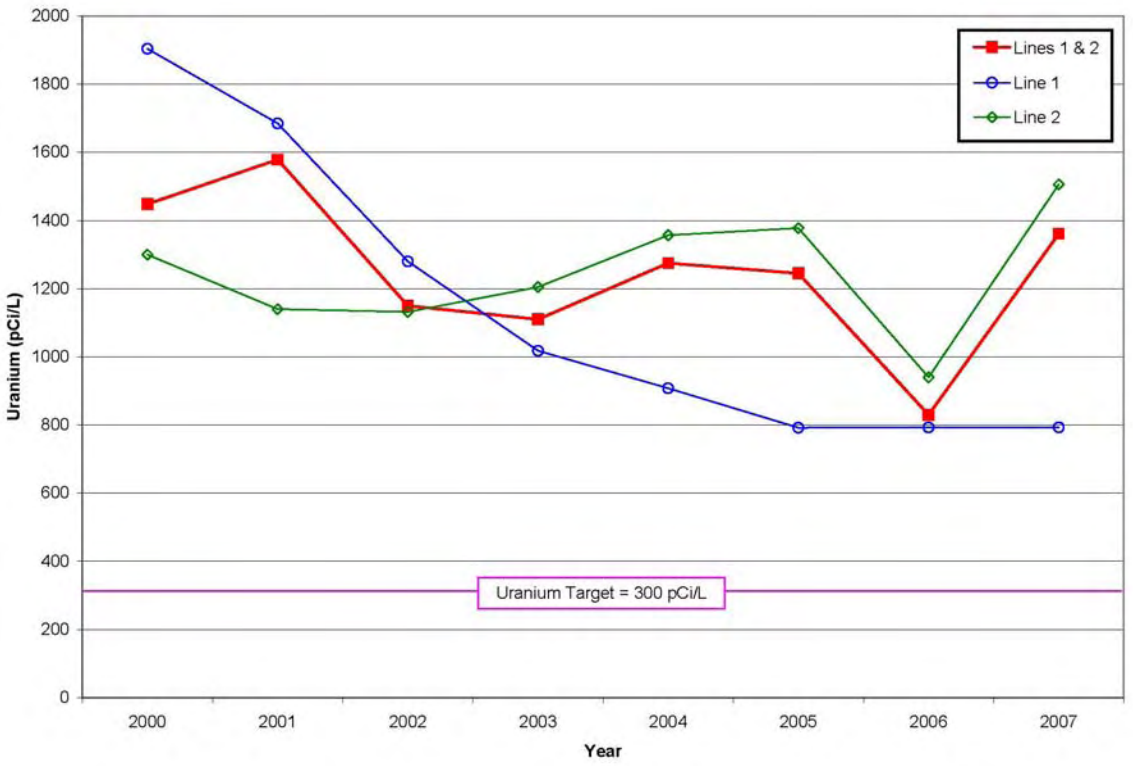

Figure 3–30. 90th Percentile of Uranium in Line 1 and 2 Wells (2000–2007)

Nitroaromatic Compounds

In 2007, samples from eight monitoring wells were analyzed for nitroaromatic compounds, primarily 2,4-DNT. These monitoring wells are those that have historically been impacted by nitroaromatic compounds along the Quarry rim or between the Quarry and Femme Osage Slough. Average concentrations of 2,4-DNT for the eight long-term locations are presented in Table 3–26. The concentrations of 2,4-DNT were above the Missouri Water Quality Standard of 0.11 µg/L at MW-1006 (0.37 µg/L to 0.49 µg/L) and MW-1027 (0.24 µg/L to 17.0 µg/L). These values are higher than those reported in 2006, but they are not historical highs.

Table 3–26. Average Concentrations of 2,4-DNT at the Weldon Spring Quarry During 2007

Location	Line	Geologic Unit	Average Concentration (µg/L)	Number of Samples
MW-1002	1	Kimmswick-Decorah	ND	3
MW-1004	1	Kimmswick-Decorah	ND	4
MW-1005	1	Kimmswick-Decorah	ND	4
MW-1006	2	Alluvium	**0.43**	2
MW-1027	2	Kimmswick-Decorah	**9.3**	4
MW-1032	2	Kimmswick-Decorah	ND	4
MW-1045	2	Alluvium	ND	4
MW-1049	2	Alluvium	ND	4

Concentrations in bold – exceeds the Missouri Water Quality Standard of 0.11 µg/L for 2,4-DNT

The concentration of 2,4-DNT has fluctuated (Figure 3–31). Increased concentrations were observed in wells MW-1006 and MW-1027 during 2005, and they decreased substantially during 2006. However, concentrations rebounded in 2007. A correlation between water level and 2,4-DNT concentration has not been determined; another viable explanation cannot be provided at this time. Concentrations less than the detection limit have historically been reported in MW-1045 and MW-1049.

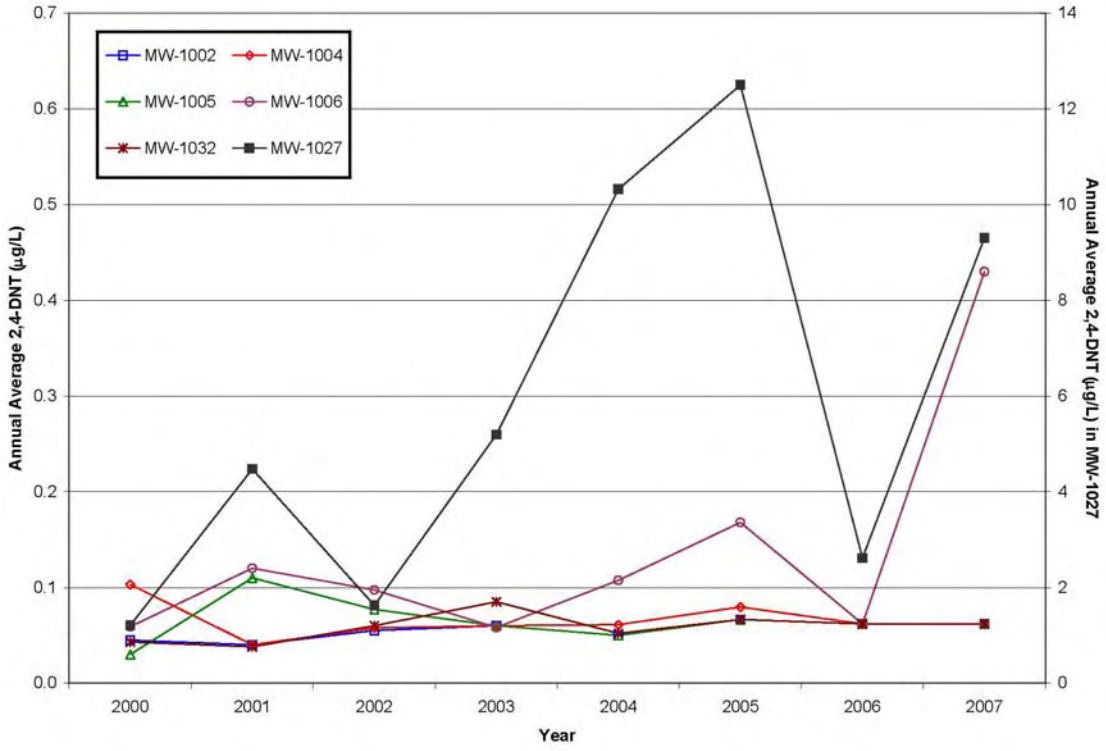

Figure 3–31. Average 2,4-DNT (µg/L) in Long-Term Wells

The attainment objective for the long-term monitoring of 2,4-DNT in groundwater north of the slough is that the 90th percentile of the data within a monitoring year is below the target level of 0.11 µg/L (DOE 2000a). The eight monitoring wells that have been selected for continued long-term monitoring were used to calculate this metric. Wells MW-1006 and MW-1027 exceeded the target level in 2007. The 90th percentile associated with the data from the eight wells was 1.39 µg/L. This value is considerably higher than previous years because a smaller set of wells is being used. Monitoring of 2,4-DNT in the eight wells will continue in 2008, and subsequent data should be evaluated.

Geochemical Parameters

The geochemistry of the shallow aquifer is monitored to verify the presence of the reduction zone and to confirm that the reduction zone is capable of the ongoing attenuation of uranium in groundwater. Groundwater is analyzed for sulfate, dissolved iron, ferrous iron, and Eh. Sulfate is monitored as an indicator of oxidation-reduction (redox) conditions in the groundwater in the vicinity of the Quarry. Higher sulfate concentrations are generally observed in an oxidizing environment. Lower sulfate levels are indicative of a more reducing environment and

precipitated from solution in a reducing environment. Iron (total dissolved and ferrous) is also monitored as an indicator of redox conditions in the groundwater. Iron concentrations generally increase in a reducing environment. These results generally correlate with observed uranium concentrations upgradient and downgradient of the reduction zone, as uranium is typically more mobile in an oxidizing environment. A summary of the geochemical parameters for each monitoring location is presented in Table 3–27.

Table 3–27. Average Values for Geochemical Parameters at the Weldon Spring Quarry During 2007

Location	Line	Geologic Unit	Average Values			
			Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	Eh (mV)
MW-1002	1	Kimmswick-Decorah	105	47.1	10.0	+172
MW-1004	1	Kimmswick-Decorah	118	41.1	17.5	+147
MW-1005	1	Kimmswick-Decorah	192	2,095	755	+45
MW-1027	1	Kimmswick-Decorah	58.6	308	288	+146
MW-1030	1	Kimmswick-Decorah	127	6,010	2,462	-27
MW-1006	2	Alluvium	83.7	50.8	42.5	+41
MW-1007	2	Alluvium	395	33,800	1,817	-29
MW-1008	2	Alluvium	102	86.7	12.5	+151
MW-1009	2	Alluvium	8.0	12,257	2,298	-34
MW-1012	2	Kimmswick-Decorah	34.6	33.0	17.5	+158
MW-1013	2	Kimmswick-Decorah	77.5	3,712	1,438	-26
MW-1014	2	Alluvium	120	306	222	+124
MW-1015	2	Kimmswick-Decorah	90.6	55.5	22.5	+108
MW-1016	2	Alluvium	92.4	150	82.5	+137
MW-1028	2	Plattin	40.3	150	55.0	+76
MW-1031	2	Alluvium	33.2	23.0	20.0	+154
MW-1032	2	Kimmswick-Decorah	110	29.2	27.5	+104
MW-1045	2	Alluvium	36.8	44.2	5.0	+104
MW-1046	2	Plattin	62.2	110	140	+157
MW-1047	2	Plattin	81.7	25.6	17.5	+123
MW-1048	2	Plattin	68.1	1,105	1,097	-8
MW-1049	2	Alluvium	0.57	54,425	5,612	-129
MW-1051	2	Alluvium	73.1	3,337	882	+32
MW-1052	2	Alluvium	47.6	35,950	12,915	-93

A review of the geochemical data indicates that reducing conditions are prevalent in the vicinity of wells MW-1007, MW-1009, MW-1049, and MW-1052. This is consistent with the uranium data (Table 3–28) where low uranium levels are detected, except in MW-1007 where elevated uranium was reported. The location of this reducing area is consistent with previous years and the attenuation of uranium in this area continues.

3.1.2.5 Monitoring Results for the Missouri River Alluvium

Groundwater quality in the Missouri River alluvium is monitored using 10 wells screened in the alluvial materials. These wells are sampled for uranium and geochemical parameters to ensure that water quality remains protective of human health. The data is discussed in the following sections.

Uranium

The six monitoring wells located immediately south of the slough (Line 3) and the RMW-series wells (Line 4) were analyzed for uranium during 2007 (Table 3–28) to verify that levels remain within the range of its natural variation in Missouri River alluvium. The results indicate that the average uranium levels were less than the statistical background value in the alluvium (Table 3–24). None of the locations south of the slough have uranium levels that exceed the drinking water standard of 20 pCi/L.

Table 3–28. Average Levels for Total Uranium in the Missouri River Alluvial Aquifer During 2007

Location	Line	Average (pCi/L)	Number of Samples
MW-1017	3	ND	2
MW-1018	3	ND	2
MW-1019	3	ND	2
MW-1021	3	ND	2
MW-1044	3	ND	2
MW-1050	3	ND	2
RMW-1	4	0.66	1
RMW-2	4	2.4	1
RMW-3	4	0.35	1
RMW-4	4	1.1	1

ND = non-detect

Geochemical Parameters

The monitoring wells located south of the slough were sampled for sulfate and iron during 2007, for the purpose of assessing redox conditions in the Missouri River alluvium in this area (Table 3–29). The data indicate that a strongly reducing environment is prevalent in the groundwater immediately south of the slough as indicated by high dissolved iron concentrations, low sulfate concentrations, and negative Eh values. This environment is not favorable for the migration of uranium, if it were to pass beyond the reducing zone north of the slough. Data from 2007 were consistent with data from previous years.

Table 3–29. Average Values for Geochemical Parameters in the Missouri River Alluvial Aquifer During 2007

Location	Sulfate (mg/L)	Dissolved Iron (µg/L)	Ferrous Iron (µg/L)	Eh (mV)
MW-1017	0.23	26,050	15,200	-137
MW-1018	3.0	33,100	11,975	-148
MW-1019	0.16	15,350	9,750	-130
MW-1021	0.36	16,500	7,600	-124
MW-1044	0.16	24,600	12,600	-153
MW-1050	12.2	17,300	7,695	-138
RMW-1	39.1	10,700	2,950	-80
RMW-2	7.5	10,700	2,900	-103
RMW-3	19.1	14,600	550	-132
RMW-4	14.1	4,200	700	-47

3.1.2.6 Quarry Trend Analysis

Testing for temporal trends was performed on total uranium and 2,4-DNT groundwater data from the Quarry collected between 2003 and 2007. These analyses were performed using the previously described nonparametric Mann-Kendall test (Section 3.1.1.7). Results for the trending analysis for uranium and 2,4-DNT are reported for Lines 1 and 2 of the Quarry monitoring network, as these lines monitor the area of groundwater impact.

The results for the Line 1 wells (Table 3–30), which are located along the Quarry rim, show that uranium concentrations over the past 5 years have generally been stable or have trended downward. Downward trends have been reported for MW-1004, MW-1005, and MW-1030 since 2003. Decreases in uranium along the Quarry rim are the result of bulk waste removal and restoration activities. Remedial activities in the Quarry have reduced and possibly prevented infiltration of precipitation and storm water into the residually contaminated fracture system in the Quarry proper. Uranium levels in MW-1027 have been variable over time.

Table 3–30. Trending Analysis for Uranium in Line 1 Groundwater Monitoring Wells

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Upper
MW-1002	20	None	-0.11	-0.24	0
MW-1004	20	Down	-48.9	-68.5	-17.6
MW-1005	20	Down	-81.5	-120	-42.4
MW-1027	20	None	-7.29	-39.5	21.1
MW-1030	20	Down	-0.84	-1.54	-0.24

The results for the Line 2 wells (Table 3–31), which are screened in the saturated alluvium or bedrock north of the Femme Osage Slough, show that in the past 5 years a few downward trends have started to be observed in uranium levels. Stable or downward levels have predominantly occurred in bedrock wells. The stabilizing or decreasing uranium levels in this area are the result of bulk waste removal and restoration activities, as previously discussed, because there is less residual source to this area. Decreases in uranium in the Line 2 wells will not occur as quickly as in the rim wells. Uranium does not bind as readily to the bedrock as it does the alluvial materials. Also, the groundwater velocity is slow in the area north of the Femme Osage Slough, resulting in less flushing; however, the distribution of uranium in groundwater is still predominantly controlled by the precipitation of uranium along the oxidizing/reducing front located north of the Femme Osage Slough. Upward trends were calculated from well MW-1007 and MW-1009. Significant increases were measured in MW-1007 2007 and have skewed the data. A slight upward trend was identified in MW-1009.

Trend analyses for 2,4-DNT was performed for wells MW-1004, MW-1006, and MW-1027 (Table 3–32), as these are the only locations that had detectable concentrations of 2,4-DNT in the last 5 years. A slight upward trend was reported for MW-1006 based on the last 5 years of data. No trend was reported for MW-1004 and MW-1027. An upward trend had previously been reported for these two locations.

Table 3–31. Trending Analysis for Uranium in Line 2 Groundwater Monitoring Wells

Location	No. of Samples	Trend	Slope (pCi/L/yr)	Confidence Intervals	
				Lower	Lower
MW-1006	20	None	-25.0	-108	51.4
MW-1007	20	Up	12.1	1.02	103
MW-1008	20	None	35.1	-408	348
MW-1009	20	Up	0.30	0.05	0.64
MW-1013	20	Down	-68.6	-94.6	-41.9
MW-1014	20	None	-125	-249	37.2
MW-1015	20	None	1.99	-8.65	13.2
MW-1016	20	None	-1.57	-8.04	6.61
MW-1028	9	None	0.18	-0.14	0.42
MW-1031	20	None	0	-0.35	0.42
MW-1032	20	Down	-69.8	-110	-47.6
MW-1045	20	None	0.68	-0.03	2.29
MW-1046	20	Down	-0.30	-0.45	-0.10
MW-1047	20	Down	-0.06	-0.12	0
MW-1048	20	None	-19.7	-31.6	0.62
MW-1051	20	None	-15.6	-190	85.2
MW-1052	20	None	-15.2	-326	3.44

Table 3–32. Trending Analysis for 2,4-DNT in Select Quarry Groundwater Monitoring Wells

Location	No. of Samples	Trend	Slope (µg/L/yr)	Confidence Intervals	
				Lower	Lower
MW-1004	20	None	---	---	---
MW-1006	18	Up	0.03	0	0.07
MW-1027	20	None	---	---	---

3.1.2.7 Recommendations – QROU Monitoring Program

Uranium levels in the Line 1 wells have been decreasing since 2000. The highest uranium levels are present in the Line 2 wells, primarily in the wells screened in the alluvium. Uranium levels in the alluvial wells within Line 2 continue to fluctuate over time; however, the levels in the bedrock wells have generally decreased since 2000. All of the Line 1 and Line 2 wells have been sampled quarterly. On the basis of the continued decreasing trends in the Line 1 wells, it is recommended that the sampling frequency in Line 1 be reduced to semiannually; however, the quarterly frequency for the Line 2 wells should be retained because uranium levels continue to vary.

The results from the Line 3 and Line 4 monitoring wells indicate that uranium levels are similar to background for the Missouri River alluvium. The sampling frequency for Line 3 and Line 4 will remain semiannual and annual, respectively.

These recommendations have been incorporated into the LTS&M Plan (DOE 2005a) for the site. It is anticipated that this document will be finalized in October 2008 and the changes implemented in calendar year 2009.

3.1.3 Disposal Cell Monitoring

Five groundwater monitoring wells, one spring, and disposal cell leachate were sampled during 2007 as part of the detection monitoring program for the permanent disposal cell. This monitoring is performed to meet the substantive requirements of 40 CFR 264, Subpart F; 10 CSR 25-7.264(2)(F); and 10 CSR 80-3.010(8). These federal and state hazardous- or solid-waste regulations were identified as ARARs for the selected remedy in the *Record of Decision for the Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (DOE 1993). These wells, the spring, and the leachate was monitored in accordance with the *Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri Site*, Appendix K (DOE 2005a).

3.1.3.1 Disposal Cell Monitoring Program

The disposal cell groundwater detection monitoring network consists of one upgradient well (MW-2055), four downgradient wells (MW-2032, MW-2046, MW-2047, and MW-2051), one downgradient spring (SP-6301), and the disposal cell leachate. Semiannual detection monitoring began in mid-1998, after cell construction had begun and waste placement activities were initiated.

The monitoring program for the disposal cell consisted of semiannual sampling for the following parameters:

- Uranium.
- Anions (chloride, fluoride, nitrate [as N], and sulfate).
- Metals (arsenic, barium, chromium, cobalt, iron, lead, manganese, nickel, selenium, and thallium).
- Nitroaromatic compounds.
- Radiochemical parameters (radium-226 [Ra-226], radium-228 [Ra-228], thorium-228 [Th-228], thorium-230 [Th-230], and thorium-232 [Th-232]).
- Polychlorinated biphenyls (PCBs) and polyaromatic hydrocarbons (PAHs).
- Miscellaneous indicator parameters (pH, specific conductance, chemical oxygen demand, total dissolved solids [TDS], and total organic carbon [TOC]).

Under the monitoring program, signature parameter (barium, iron, manganese, and uranium) data from each monitoring event are compared to the baseline tolerance limits (BTLs) to trace general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. Tolerance limits for signature parameters have been calculated using the dataset from 1997 through 2002, using 95 percent confidence limits.

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if there are changes in the groundwater system. Data are compared to the three most recent years of data to determine if

statistically significant changes in concentrations are present. A measured concentration is considered statistically significant if it is greater than the arithmetic mean plus three times the standard deviation for a given location.

Wells with data showing statistically significant increases or decreases are re-sampled to confirm the exceedence. If the results of the re-sampling confirm the exceedence, historical leachate analytical data and volumes are evaluated to assess the integrity of the disposal cell. If the leachate data do not indicate that the exceedance could be the result of leakage from the cell, an assessment of the analytical data and review of site-wide monitoring data is performed. If the exceeding parameter is a contaminant of concern for the GWOU, this information is evaluated under the monitoring program for that operable unit.

3.1.3.2 Disposal Cell Monitoring Results

The 2007 monitoring results for the signature parameters are presented in Table 3–33 along with applicable BTLs. The results were less than the applicable BTLs which indicates that there is no evidence of leakage in the groundwater beneath the disposal cell. The general groundwater quality (Table 3–34) in the detection monitoring wells and springs was similar to that measured in 2006.

The 2007 monitoring results for the disposal cell leachate are presented in Table 3–35. The LCRS is sampled semiannually for disposal cell well analytes, and the data are used for comparison with corresponding concentrations in wells if elevated levels of constituents are identified in the groundwater. The composition of the leachate is similar to that measured in 2006.

In general, the composition of the leachate has remained stable over the past 5 years, with the exception of iron, manganese, and uranium. These three constituents have shown a general decline. Increasing concentrations over time have not been identified in any of the monitored constituents in the leachate.

Table 3–33. Signature Parameter Results and Associated BTLs at Disposal Cell Monitoring Locations for 2007

Parameter	Location	BTL	Results	
			June 2007	December 2007
Barium (µg/L)	MW-2032	337	135	165
	MW-2046	277	204	205
	MW-2047	471	344	329
	MW-2051	285	187	190
	MW-2055	98	17.7	18.3
	SP-6301	180	131	125
Iron (µg/L)	MW-2032	1,125	< 20	< 20
	MW-2046	1,578	373	414
	MW-2047	1,485	27.3	< 20
	MW-2051	2,896	< 20	< 20
	MW-2055	10,579	< 20	46.5
	SP-6301	2,608	28.7	197
Manganese (µg/L)	MW-2032	57	< 2.5	< 2.5
	MW-2046	187	24.5	27.5
	MW-2047	171	6.2	< 5
	MW-2051	265	< 2.5	< 2.5
	MW-2055	179	< 2.5	< 5
	SP-6301	88	< 2.5	4.6
Uranium (pCi/L)	MW-2032	6.4	4.2	2.4
	MW-2046	1.8	1.2	1.0
	MW-2047	2.7	1.3	1.2
	MW-2051	4.5	1.3	1.2
	MW-2055	7.5	2.5	1.9
	SP-6301	159	74.5	47.8

3.1.3.3 Groundwater Flow

Groundwater flow rate and direction are evaluated annually as specified in the *Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri Site*, Appendix K (DOE 2005a). The groundwater flow direction was determined by constructing a potentiometric surface map of the shallow aquifer using the available wells at the Chemical Plant (Figure 3–19). The configuration of the potentiometric surface has remained relatively unchanged since the construction of the disposal cell. The groundwater flow direction is generally to the north. A groundwater divide is present along the southern boundary of the Site.

The average groundwater flow rate (average linear velocity) is calculated using the following equation:

$$v = -Ki/n_e$$

Table 3–34. Average Values for Monitoring Data for the Disposal Cell Well Network 2007

Parameter	MW-2032	MW-2046	MW-2047	MW-2051	MW-2055	SP-6301
Chloride (mg/L)	2.4	40.0	7.5	12.0	4.4	25.3
Fluoride (mg/L)	0.16	0.12	0.07	0.14	0.09	0.14
Nitrate-N (mg/L)	2.6	2.4	80.7	1.8	1.4	4.2
Sulfate (mg/L)	33.8	62.2	24.6	18.4	256	25.8
Arsenic (µg/L)	ND	ND	ND	ND	ND	ND
Chromium (µg/L)	ND	3.0	4.0	ND	4.0	ND
Cobalt (µg/L)	ND	ND	ND	ND	ND	ND
Lead (µg/L)	ND	ND	ND	ND	ND	ND
Nickel (µg/L)	5.0	9.0	ND	ND	11.0	ND
Selenium (µg/L)	ND	5.0	ND	ND	ND	ND
Thallium (µg/L)	ND	ND	ND	ND	ND	ND
COD (mg/L)	20.5	7.5	21.0	15.0	7.3	25.0
TDS (mg/L)	310	617	758	406	747	328
TOC (mg/L)	ND	1.9	0.8	ND	ND	1.4
1,3,5-TNB (µg/L)	ND	2.7	ND	ND	ND	ND
1,3-DNB (µg/L)	ND	ND	ND	ND	ND	ND
2,4,6-TNT (µg/L)	ND	5.2	ND	0.10	ND	ND
2,4-DNT (µg/L)	ND	0.15	0.07	0.07	ND	ND
2,6-DNT (µg/L)	ND	1.6	0.17	ND	ND	0.10
NB (µg/L)	ND	ND	ND	ND	ND	ND
Radium-226 (pCi/L)	0.24	0.23	0.46	0.25	0.20	0.26
Radium-228 (pCi/L)	ND	ND	0.50	ND	ND	ND
Thorium-228 (pCi/L)	ND	ND	ND	ND	ND	ND
Thorium-230 (pCi/L)	0.20	0.26	0.26	ND	0.33	0.18
Thorium-232 (pCi/L)	ND	ND	ND	ND	ND	ND
PCBs/PAHs (µg/L)	ND	ND	ND	ND	ND	ND
DO (mg/L)	4.5	7.0	5.3	8.3	6.8	8.0
ORP (mV)	127	177	209	182	195	246
pH (s.u.)	7.2	6.9	6.9	7.0	7.0	7.1
SC (µmohs/cm)	567	950	1,184	648	1,020	476
Temperature (C)	13.8	15.6	13.2	14.9	15.1	11.1

ND = Non-detect.

Table 3–35. Summary of Disposal Cell Leachate Monitoring Data During 2007

Parameter	Concentrations	
	June 2007	December 2007
Chloride (mg/L)	35.6	38.7
Fluoride (mg/L)	0.26	0.19
Nitrate-N (mg/L)	1.3	0.77
Sulfate (mg/L)	37.5	27.0
Arsenic (µg/L)	4.8	ND
Barium (µg/L)	781	830
Chromium (µg/L)	ND	ND
Cobalt (µg/L)	ND	5.1
Iron (µg/L)	4,130	3,590
Lead (µg/L)	ND	ND
Manganese (µg/L)	389	477
Nickel (µg/L)	6.4	9.1
Selenium (µg/L)	ND	ND
Thallium (µg/L)	ND	7.9
COD (mg/L)	69.0	41.0
TDS (mg/L)	725	665
TOC (mg/L)	12.0	13.5
1,3,5-TNB (µg/L)	ND	ND
1,3-DNB (µg/L)	ND	ND
2,4,6-TNT (µg/L)	ND	ND
2,4-DNT (µg/L)	ND	ND
2,6-DNT (µg/L)	ND	ND
NB (µg/L)	ND	ND
Radium-226 (pCi/L)	0.56	0.57
Radium-228 (pCi/L)	0.79	ND
Thorium-228 (pCi/L)	ND	ND
Thorium-230 (pCi/L)	ND	0.41
Thorium-232 (pCi/L)	ND	ND
Uranium (pCi/L)	17.1	2.7
PCBs/PAHs (µg/L)	ND	ND

ND = Non-detect.

The average hydraulic conductivity (K) using data from the cell monitoring wells is 7×10^{-3} centimeters per second. An effective porosity (n_e) of 0.10 was selected to estimate the maximum groundwater flow rate in this area. The hydraulic gradient (i) in the disposal cell area is 0.011 ft per foot and is based on data from MW-2032 and MW-2055, located 2,100 ft apart. This approach is consistent with the calculations presented in the *Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri Site*, Appendix K. The average flow rate for 2007 was 2.2 ft per day, which is the same as the average flow rate calculated in 2005 and 2006 and similar to the average flow rates calculated since 1998 (DOE 2005a).

3.1.3.4 Recommendations – Disposal Cell Monitoring Program

The general groundwater quality beneath the disposal cell has been sampled and has shown little variation. In general, the composition of the leachate has also remained stable, with the exception of iron, manganese, and uranium. These three constituents have shown a general decline over time.

It was anticipated during development of the detection monitoring program that the list of signature parameters may be modified, as necessary, based on future changes in leachate or groundwater concentrations. Barium, iron, manganese, and uranium were identified as signature parameters in 2004. A comparison of the annual averages for the four signature parameters in the leachate and cell wells or Burgermeister Spring indicates that the concentration of iron and manganese in the leachate have decreased to levels that no longer exceed those detected in the groundwater by an order of magnitude. Although the levels of uranium in the leachate have decreased, the levels are still an order of magnitude greater than those detected in groundwater. On the basis of the evaluation, it is concluded that barium and uranium will continue to be monitored as signature parameters under the detection monitoring program. Starting in 2008, iron and manganese will no longer be considered signature parameters. These two analytes will be monitored for general groundwater quality.

The monitoring program must include those constituents that have been detected in the groundwater and that are reasonable expected to be in or derived from waste in the disposal cell. Based on the review of the groundwater and leachate data, the following reduced list of parameters will continue to be monitored in the five disposal cell wells and Burgermeister Spring: arsenic, barium, chromium, lead, manganese, nickel, selenium, thallium, nitroaromatic compounds, radium-226/228, thorium-228/230/232, PAHs, and PCBs. These constituents have been identified as contaminants of concern for either the Chemical Plant or Quarry Bulk Wastes OU or they were generated during water treatment processes during remedial activities. The leachate will continue to be monitored for the present list of parameters.

These recommendations have been incorporated into the LTS&M Plan (DOE 2005a) for the site. It is anticipated that this document will be finalized in October 2008.

3.2 Surface Water

3.2.1 Chemical Plant Surface Water

The surface water locations, Schote Creek, Dardenne Creek, and Busch Lakes 34, 35, and 36 (Figure 3–32), were sampled once during 2007 for total uranium. This monitoring was conducted to measure the effects of groundwater and surface water discharges from the Site on the quality of downstream surface water.

The results for the Chemical Plant surface water sampling are presented in Table 3–36 along with the recent 3-year high for each location, for comparison. Uranium levels at the off-site surface water locations for 2007 were similar to 2006 averages. The uranium levels at Busch Lake 34 continue to be elevated compared to the remainder of the locations; however, uranium levels at the Busch Lake outlets have shown an overall decline since remediation started. The Schote Creek and Dardenne Creek locations are downstream of the lakes and have always shown relatively low levels because the Chemical Plant portion of the watershed is much smaller than the total watershed area. These results are consistent with data from previous years.

Table 3–36. 2007 Average Concentrations of Total Uranium at Weldon Spring Chemical Plant Area Surface Water Locations

Location	Uranium (pCi/L)	Recent 3-Year High [a]
SW-2004 (Lake 34)	8.1	8.9
SW-2005 (Lake 36)	3.4	3.4
SW-2012 (Lake 35)	2.4	4.1
SW-2016 (Dardenne)	1.0	1.6
SW-2024 (Schote)	2.2	2.3

[a]2004−2006

3.2.2 Quarry Surface Water

Four locations within Femme Osage Slough were sampled twice during 2007 to assess the water quality in the slough and the potential impact of groundwater from north of the slough (Table 3–37). Occasionally, groundwater north of the slough will discharge into the slough when the water table is high. These sampling sites, shown in Figure 3–32, are located in the upper section of the slough, which is adjacent to the area of groundwater impact. Samples were not collected from two locations during the first half of the year because the slough did not contain water in those areas.

Table 3–37. 2007 Total Uranium at Weldon Spring Quarry Surface Water Locations

Location	S1	S2	Average (pCi/L)	Recent 3-Year High (pCi/L)
SW-1003	48.9	40.2	44.6	33.1
SW-1004	26.9	39.7	33.3	91.3
SW-1005	NS	17.2	17.2	25.6
SW-1010	NS	12.7	12.7	24.9

NS = not sampled (slough was dry)

Uranium levels measured in 2007 at locations SW-1003 and SW-1004 were slightly higher than those measured in 2005 and 2006 (Figure 3–33). These locations are close to the area of groundwater impact and may represent the temporary influence of uranium impacted groundwater discharging into the slough during periods of higher groundwater levels.

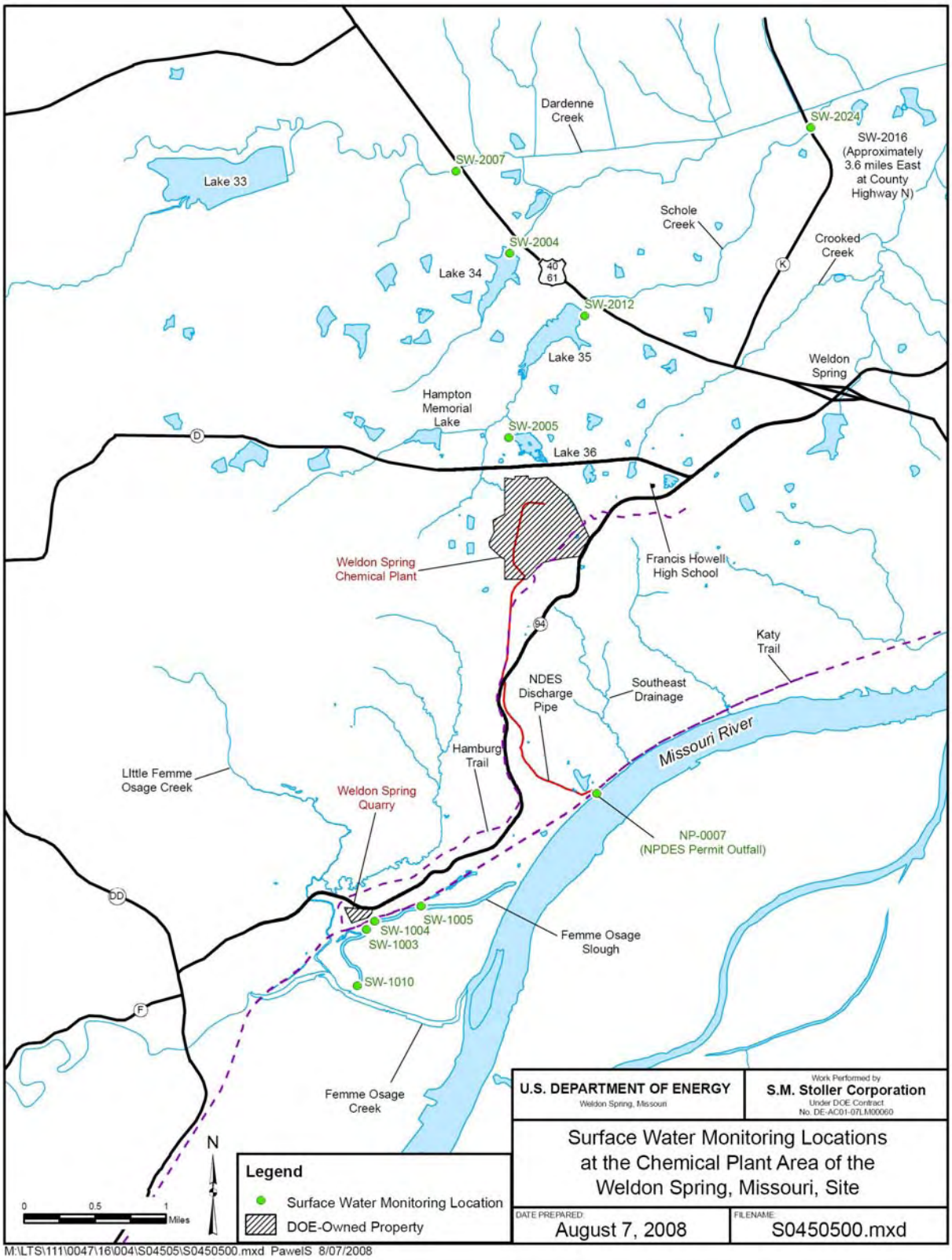

Figure 3–32. Surface Water Monitoring Locations at the Chemical Plant Area of the Weldon Spring, Missouri, Site

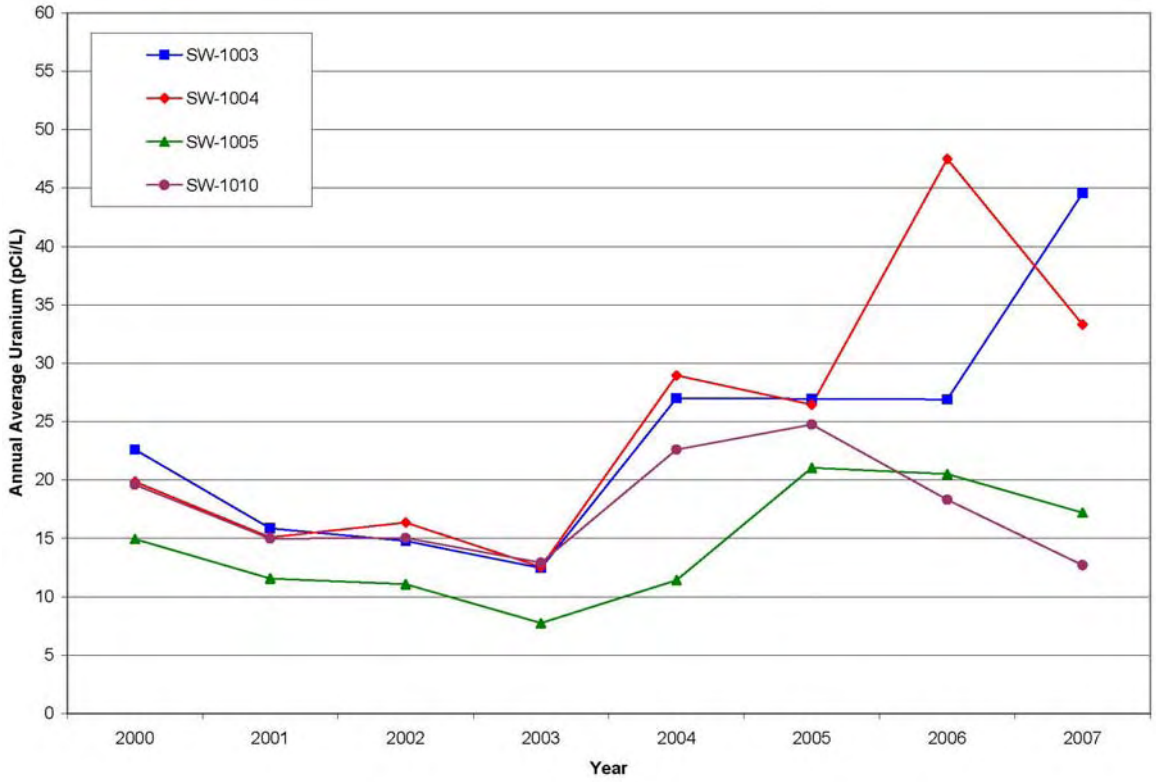

Figure 3–33. Uranium Levels in the Slough

3.3 Leachate Collection and Removal System

The LCRS collects leachate from the disposal cell. The leachate continued to be sampled in accordance with the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan* (DOE 2004b). The leachate analytical data for 2007 were discussed previously in Section 3.1.3.2 and are shown in Table 3–35.

As needed, the leachate is pumped from the sump, pretreated, and then transported to MSD for final treatment in their Bissell Point plant wastewater treatment facility. A sample of leachate is collected and analyzed in accordance with MSD requirements for each hauling event. MSD requirements for the leachate are discussed in Section 2.1.3.3.

Uranium concentrations in untreated leachate during 2007 averaged approximately 18 pCi/L. The uranium concentration data were slightly lower than data from 2006, when uranium levels were near 20 pCi/L. The actual uranium concentrations in the untreated leachate are shown on Figure 3–34.

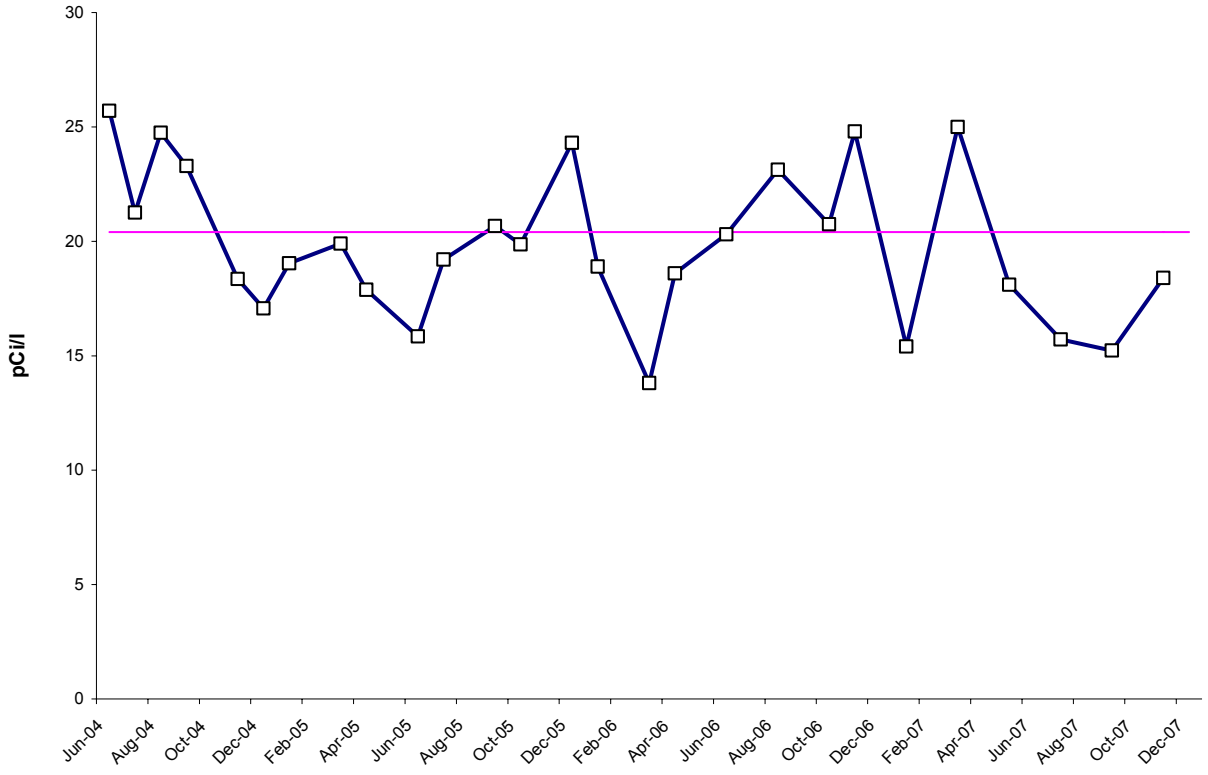

Figure 3–34. Actual Uranium Concentrations in the Primary Leachate

Every 2 weeks, the leachate flow rates at the disposal cell are monitored, and the LCRS is inspected. The leachate levels were recorded on a data logger and downloaded at least once per month. The regulations in 40 CFR 264.303(c) only require monthly recording and, if stable, quarterly flow recording thereafter. Leachate flow rates are reported in units of gallons per day and compared to the action leakage rate of 100 gallons per acre per day established for the secondary (or lower) leachate collection system.

During 2006 and 2007, discharge from the primary leachate collection system generated approximately 135 gallons per day and 119 gallons per day, respectively. The daily averages for the primary leachate flow rates are shown on Figure 3–35. The combined leachate flow rate from the secondary leachate collection system averaged approximately 12.0 gallons per day during 2006 and 10.8 gallons per day in 2007. On a per-acre basis, the average leakage rate for the secondary leachate collection system between 2006 and 2007 was approximately 0.50 and 0.45 gallons per acre per day. This rate continues to be significantly less than 1 percent of the action leakage rate of 100 gallons per acre per day.

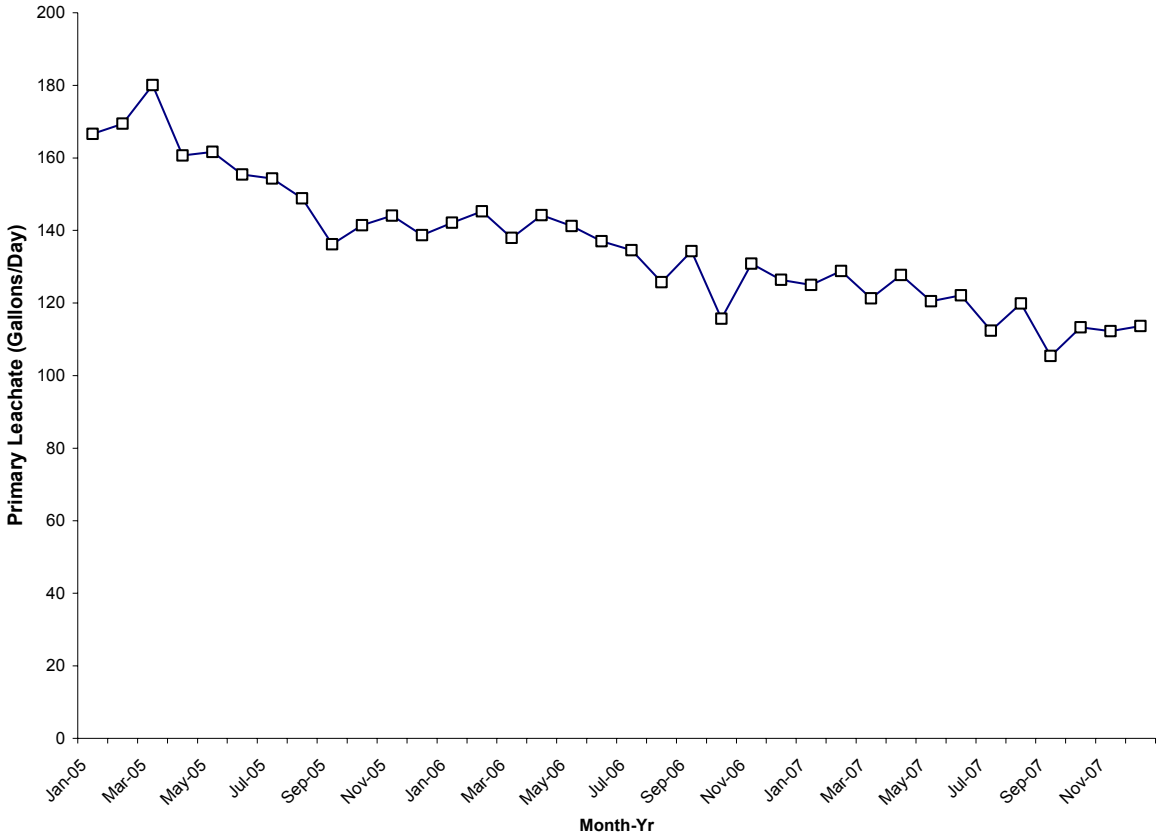

Figure 3–35. Daily Averages of the Primary Leachate Flow

3.4 Air

In the past, the WSSRAP operated an extensive environmental airborne monitoring and surveillance program in accordance with DOE orders, EPA and National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations, and the WSSRAP *Environmental Monitoring Plan* (DOE 2003a). Throughout the remediation of contaminated soils and materials, the potential for airborne releases and atmospheric migration of radioactive contaminants was closely monitored by measuring concentrations of radon, gamma exposure, airborne radioactive particulates, airborne asbestos, and fine particulate matter at various site perimeter and off-site locations. The potential for airborne release of radionuclides was eliminated with the final disposition of contaminated materials in the permanent disposal cell. With the completion of most Site activities, no air monitoring has been conducted since 2001 (DOE 2001a).

3.5 Radiation Dose Analysis

This section evaluates the potential effects of remaining surface water and groundwater discharges of radiological contaminants from the Weldon Spring Site in 2007. Effective dose equivalent has been calculated for 2007 based on the applicable exposure pathway. Doses resulting from airborne emissions are no longer calculated since the potential for airborne release of radiological contaminants has been eliminated and, therefore, 40 CFR 61, Subpart H "National Emission Standards for Emissions of Radionuclides other than Radon From

Department of Energy Facilities" regulations are no longer relevant. Similarly, doses resulting from external gamma radiation are no longer calculated since the radon sources have been remediated and are contained within the permanent disposal cell. The cell cover effectively mitigates radon releases to levels comparable to background locations.

For this report, the potential exposure in terms of dose to an individual who consumes spring water contaminated with uranium is calculated. This calculation represents that exposure for the reasonable maximally exposed (RME) individual since data from the spring with the highest uranium concentration is used (i.e., for Burgermeister Spring with a reported uranium concentration of 74.5 pCi/L for 2007). The estimated total effective dose equivalent (TEDE) to this RME is about 0.16 mrem (1.7 E-3 mSv). This result is compared to DOE limits contained in DOE Order 5400.5 to demonstrate compliance with regulatory requirements.

3.5.1 Pathway Analysis and Exposure Scenario

In developing specific elements of the Weldon Spring Site environmental monitoring program, potential exposure pathways and health effects of the radioactive and chemical materials present on site are evaluated to determine if potential pathways of exposure exist. Under current Site conditions, the only potential pathway to consider is that of a recreational visitor to the Weldon Spring Conservation Area possibly coming into contact with spring water specifically at Burgermeister Spring. A dose calculation for a population within 80 km (49.6 miles) of the Site is not estimated since airborne release of radioactive contaminants is not a factor.

Consumption of contaminated groundwater both at the Chemical Plant/former Raffinate Pits and the Quarry areas is not a pathway of concern under current conditions as no drinking water wells are located in the vicinity of the contaminated groundwater in the Chemical Plant and Raffinate Pit area, and there is no access to the impacted groundwater at the Quarry area. Concentrations of uranium in the production wells near the Weldon Spring Quarry are comparable to background concentrations.

The inhalation of airborne particulates, radon gas, and external gamma irradiation pathways are also no longer pathways of concern since the contaminated soils and other materials have been remediated and placed in the on-site cell. Hence, these pathways were not included in the dose estimates for 2007.

The radiological public dose guideline contained in DOE Order 5400.5 is applicable for comparing potential doses at the Weldon Spring Site. This guideline provides for an annual limit of 100 mrem (1 mSv) total effective dose equivalent accounting for all exposure pathways (excluding background).

3.5.2 Dose Equivalent Estimates

The TEDE estimate for the exposure scenario was calculated using 2007 environmental monitoring data. The dose is well below the standards set by DOE for annual public exposure.

This section discusses the estimated total effective dose equivalent to a hypothetical individual assumed to frequent Burgermeister Spring of the Weldon Spring Conservation Area. No private residences are adjacent to Burgermeister Spring, which is situated on land currently managed by

MDC. Therefore, the calculation of dose equivalent is based on a recreational user of the Conservation Area who drank from Burgermeister Spring 20 times per year during 2007.

Exposure scenario assumptions particular to this dose calculation include the following:

- The maximally exposed individual drank one cup (0.2 liter [L]) of water from the spring 20 times per year (equivalent to 1.05 gallons [4.0 L] of water for the year).
- The maximum uranium concentration in water samples taken from spring locations during 2007 was found at Burgermeister Spring (74.5 pCi/L). This concentration was assumed to be present in all of the water ingested by the maximally exposed individual

On the basis of the natural uranium activity ratios (U-234: 49.1 percent, U-235: 2.3 percent, and U-238: 48.6 percent), the dose conversion factors (DCFs) for ingestion for U-238 and U-234 were used for calculating the dose. These DCFs are 2.69E-4 mrem/pCi and 2.83E-4 mrem/pCi for U-238 and U-234, respectively (Eckerman 1988).

The TEDE is calculated as shown below:

TEDE (ingestion of contaminated water for uranium) = Concentration (pCi/L) × Volume of Water Ingested (l) × DCF (U-238 + U-234) (mrem/pCi)

TEDE (total uranium) = 74.5 pCi/L × 4L × (2.69 E-4 mrem/pCi + 2.83E-4 mrem/pCi) = 0.17 mrem (1.7 E-3mSv)

This value represents less than 0.16 percent of the DOE standard of 100 mrem (1 mSv) TEDE above background. In comparison, the annual average exposure to natural background radiation in the United States results in a TEDE of approximately 300 mrem (3 mSv) (Beir 1990).

4.0 Environmental Quality

4.1 Highlights of the Quality Assurance Program

Quality assurance for sampling activities for 2007 followed the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2006a).

- Average relative percent differences calculated for groundwater, surface water, and springs were calculated.
- Trip and equipment blanks were assessed and summarized.
- The data validation program accepted 98.1 percent of the all data in 2007 (including field data).

4.2 Program Overview

The environmental quality assurance program includes management of the plans and procedures governing environmental monitoring activities at the Weldon Spring Site and at the subcontracted off-site laboratories. This section discusses the environmental monitoring standards at the Weldon Spring Site and the goals for these programs, plans, and procedures.

The environmental quality assurance program provides the Weldon Spring Site with reliable, accurate, and precise monitoring data. The program furnishes guidance and directives to detect and prevent quality problems from the time a sample is collected until the associated data are evaluated and utilized. Key elements in achieving the goals of this program are compliance with the quality assurance program and environmental quality assurance program procedures; the use of quality control samples; complete documentation of field activities and laboratory analyses; and reviews of data documentation for precision, accuracy, and completeness (data validation).

The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* summarizes the data quality requirements for collecting and analyzing environmental data. The LTS&M Plan (DOE 2005a) lists the sampling locations and provides site-specific detail for quality control samples. These plans describe administrative procedures for environmental data management, data validation, database administration, and data archiving.

Analytical data are received from subcontracted analytical laboratories. Uncensored data have been used for reporting and calculating annual averages (when available). When there was no instrument response, non-detect data were used in calculations of averages at a value of one-half the detection limit.

4.2.1 Applicable Standards

Applicable standards for environmental quality assurance include the following: (1) use of the approved analytical and field-measurement methodologies; (2) collection and evaluation of quality control samples; (3) accurate, precise, and complete evaluations; and (4) the preservation and security of all applicable documents and records pertinent to the environmental-monitoring program.

4.2.2 Analytical and Field Measurement Methodologies

Analytical and field measurement methodologies used at the Weldon Spring Site comply with applicable standards required by DOE, EPA, and the American Public Health Association. Analytical methodologies used by subcontracted laboratories for environmental monitoring primarily follow the EPA SW-846 requirements and the EPA drinking water and radiochemical methodologies or methods that are reviewed prior to analysis. Field measurement methodologies typically follow the American Public Health Association's *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1992).

4.3 Quality Control Samples

Quality control samples for environmental monitoring are collected in accordance with the required sampling plan, which specifies how frequently quality control samples should be collected. Quality control samples are normally collected in accordance with guidelines. Descriptions of the quality control samples collected at the Weldon Spring Site are detailed in Table 4–1.

Table 4–1. Quality Control Sample Description

Type of Quality Control Sample	Description
Equipment Rinsate Blank	Monitors the effectiveness of decontamination procedures used on non-dedicated sampling equipment. Equipment blanks include rinsate and filter blanks.
Trip Blank	Monitors volatile organic compounds that may be introduced during transportation or handling at the laboratory. Trip blanks are collected with distilled water in the Weldon Spring Site laboratory.
Field Duplicate	Monitors field conditions that may affect the reproducibility of samples collected from a given location. Field replicates are collected in the field at the same location.
Matrix Spike[a]	Assesses matrix and accuracy of laboratory measurements for a given matrix type. The results of this analysis and the routine sample are used to compute the percent recovery for each parameter.
Matrix Duplicate[a]	Assesses matrix and precision of laboratory measurements for inorganic parameters in a given matrix type. The results of the matrix duplicate and the routine sample are used to compute the relative percent difference for each parameter.
Matrix Spike Duplicate[a]	Assesses matrix and precision of laboratory measurements for organic compounds. The matrix spike duplicate is spiked in the same manner as the matrix spike sample. The results of the matrix spike and matrix spike duplicate are used to determine the relative percent difference for organic parameters.

[a]A laboratory sample is split from the parent sample.

4.3.1 Quality Control Sample Results

The quality control program is assessed by analyzing the results of quality control samples and comparing them to the actual samples, using the following methodology.

4.3.2 Duplicate Results Evaluation

Field duplicate analyses were evaluated in 2007. The matrix duplicate analyses were performed at subcontracted laboratories from aliquots of original samples collected at the Weldon Spring Site and are not summarized in this document. Matrix duplicates were used to assess the

precision of analyses and also to aid in evaluating the homogeneity of samples or analytical interference of sample matrixes. Matrix duplicates were assessed during the data validation process for each sample group.

Generally, field duplicate samples were analyzed for the same parameters as the original samples and were collected at the rate of approximately one for every 20 samples. In 2007, 18 field duplicates were collected from 243 locations sampled (7.4 percent). Typically, duplicate samples were analyzed for the common parameters (e.g., uranium, inorganic anions, metals).

When field duplicate samples were available, the average relative percent difference (RPD) was calculated. This difference represents an estimate of precision. The equation used was:

$$RPD = |S–D| /[(S+D] /2) \times 100 \text{ percent}$$

Where: S = concentration in the normal sample
D = concentration in the duplicate analysis

Table 4–2 summarizes the calculated RPD for field duplicate samples for groundwater, springs, and surface water matrices. Parameters that were not commonly analyzed for or that were not contaminants of concern were not evaluated. The RPD was calculated only for samples whose analytical results exceeded 5 times the detection limit and did not have any quality control problems (i.e., blank contamination).

Table 4–2. Summary of Calculated RPDs

Parameter	Number of Samples	Avg. RPD
Uranium	12	9.0
Iron	7	9.4
Barium	2	1.3
Nitrate-N	7	17.0
Chloride	2	4.3
Sulfate	9	5.6
Fluoride	2	5.6
Total Dissolved Solids	2	3.5
Total Organic Carbon	2	7.6
Nitroaromatics	6	9.0
Manganese	2	15.9
Nickel	1	4.8

The results in Table 4–2 demonstrate that average RPDs calculated were within the 20 percent criterion. Several individual parameters exceeded the 20 percent criteria and were assessed in the data validation reports. As a result, the average field duplicate sample analyses in 2007 were of acceptable quality.

4.4 Blank Sample Results Evaluation

Various types of blanks are collected to assess the conditions or contaminants that may be introduced during sample collection and transportation. These conditions and contaminants are

monitored by collecting blank samples to ensure that environmental samples are not being contaminated. Blank samples evaluate the:

- Environmental conditions under which the samples (i.e., volatile analyses) were shipped (trip blanks).
- Ambient conditions in the field that may affect a sample during collection (trip blanks).
- Effectiveness of the decontamination procedure for sampling equipment used to collect samples (equipment blanks).

Sections 4.4.1 and 4.4.2 discuss the sample blank analyses and the potential impact of blank contamination upon the associated samples.

4.4.1 Trip Blank Evaluation

Trip blanks are collected to assess the impact of sample collection and shipment on groundwater and surface water samples analyzed for volatile organic compounds. Trip blanks are sent to the laboratory with each shipment of volatile organic samples.

In 2007, nine trip blanks were analyzed for volatile organic compounds. No compounds were detected in the trip blanks. All environmental samples associated with these trip blank samples were evaluated, and it was determined that no samples were impacted.

4.4.2 Equipment Blank Evaluation

Equipment blanks are samples that are collected by rinsing decontaminated equipment with distilled water. The collected rinse water is then analyzed for contaminants of concern. This procedure is used to determine the effectiveness of the decontamination process. At the Weldon Spring Site, most of the groundwater samples are collected from dedicated equipment (e.g., pumps, dedicated bailers), and spring water is collected by placing the sample directly into a sample container. Therefore, no equipment blanks are required for groundwater or spring locations.

Surface water is collected using a dip cup or similar container. An equipment blank (rinsate) is collected to assess the cleanliness of the equipment. Two equipment rinsate blanks were collected in 2007 to assess the dip cups used for surface water sampling. Samples were analyzed for only total uranium. Uranium was not detected in either blank, and therefore, there was no concern of cross contamination in the dip cups in 2007.

4.5 Data Validation Program Summary

The data validation program at the Weldon Spring Site follows the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2006a). This program involves reviewing and qualifying 100 percent of the data collected during a calendar year. The data points represent the number of parameters analyzed (e.g., toluene), not the number of physical analyses performed (e.g., volatile organics analyses).

Table 4–3 identifies the number of quarterly and total data points that were validated in 2007 and indicates the percentage of those selected that were complete. Data points in this table include all sample types (including field parameters).

Table 4–3. Validation Summary for Calendar Year 2007

Calendar Quarter	No. of Data Points Validated	No. of Validated Data Points Rejected	Completeness[a]
Quarter 1	715	27	96.2
Quarter 2	1351	17	98.7
Quarter 3	503	4	99.2
Quarter 4	1364	27	98.0
2007 Total	3933	75	98.1

[a]Completeness is a measure of acceptable data. The value is determined by the following equation:

$$\text{Completeness} = \frac{(\#\text{ validated} - \#\text{ rejected})}{\#\text{ validated}}$$

Reflects all validatable data for the calendar year.

Table 4–4 identifies validation qualifiers assigned to the selected data points as a result of data validation. The Weldon Spring Site validation technical review was performed in accordance with the *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (DOE 2006a). For calendar year 2007, 100 percent of data validation had been completed. Data points in this table include groundwater, leachate, surface water, and spring water samples.

Table 4–4. Validation Qualifier Summary for Calendar Year 2007

	Number of Data Points								
	Field	**Anions**	**Metals**	**Misc.**	**Nitro-Aromatics**	**Radio-Chemical**	**Semi-Volatiles**	**Volatiles**	**Total**
Accepted	1182	238	637	313	852	101	400	135	3858
Rejected	17	0	0	0	58	0	0	0	75
Not Validatable	0	0	0	0	0	0	0	0	0
Total	1199	238	637	313	910	101	400	135	3933
Percentages									
Accepted	98.5%	100%	100%	100%	93.6%	100%	100%	100%	98.1%
Rejected	1.5%	0%	0%	0%	6.4%	0%	0%	0%	1.9%
Not Validatable	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

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5.0 Long-Term Surveillance and Maintenance

The Site has entered the LTS&M phase of the project. The status of LTS&M activities that took place during 2007 is discussed in this section of the report.

5.1 LTS&M Plan

The LTS&M Plan (DOE 2005a) took several years to develop. It was issued for several rounds of regulator and stakeholder review and comments, and several public meetings and workshops were held on the development of this plan. The final plan was issued in July 2005. Minor revisions were issued as an appendix to the 2005 *Annual Site Environmental Report*. The LTS&M Plan was revised and issued for comment to the State and EPA in April 2008.

5.2 Institutional Controls

The LTS&M Plan includes Section 3, "Institutional Controls Implementation Plan for the Weldon Spring Site," which summarizes information pertinent to the implementation of ICs to meet the objectives of the use restrictions described in the Explanation of Significant Differences (ESD) (DOE 2005b) issued in February 2005. Section 3 of the LTS&M Plan includes current Site conditions and the risk-basis for why restrictions are needed, the objectives of the use restrictions, specific ICs already in place, and additional mechanisms identified for implementation. The schedule, which is included in the LTS&M Plan, and the status for implementing the additional ICs are discussed below.

1) Special Area Designation Under the State Well Drillers' Act—DOE will submit a package that proposes special area designation to MDNR within 4 months of the effective date of this plan.

   Status: DOE and its contractor traveled to Kansas City, Missouri, and met with the U.S. Army Corps of Engineers and the 89th Readiness Reserves (Army) on September 15, 2005, to coordinate a request for special area designation for the overlapping contaminated groundwater areas from both sites. Both parties collaborated on a combined presentation for the Missouri Well Installation Board at its regularly scheduled meeting on November 4, 2005, in Springfield, Missouri.

   DOE and its contractor participated in a meeting with the Army and MDNR on October 18, 2005, in Rolla, Missouri, to discuss the presentation for the Missouri Well Installation Board.

   DOE and the Army made their presentation to the Missouri Well Installation Board at their regularly scheduled meeting on November 4, 2005. The presentation covered the history of and background for the two sites and a request for a Special Area Designation for the groundwater restricted areas.

   On December 13, 2005, MDNR held an informational meeting at the Weldon Spring Site to present information regarding the Special Use Area Designation for the DOE and Army sites and to receive feedback from stakeholders and the public.

   On February 20, 2006, DOE and the Army attended a regularly scheduled meeting of the Missouri Well Installation Board in Lake Ozark, Missouri, answering specific questions from the Board. The Board decided on certain elements of the proposal, including the size

and shape of the Special Area and the method for imposing the restrictions via advance consultation between the drillers and MDNR. The Board thus decided to proceed with rulemaking process, but it did not vote on the action. Instead, the Board directed MDNR staff to prepare a revised draft rule based on the meeting and to present it for a vote at the next meeting.

On May 19, 2006, DOE and the Army attended the regularly scheduled meeting of the Board at the Weldon Spring Site. The location had been selected by the Board to facilitate participation from the local community, as well as to provide an opportunity for Board members to gain knowledge of the Weldon Spring Site and visit the proposed restriction areas. The Board voted at this meeting and passed the draft regulation as prepared by MNDR staff.

A draft of the rule was published in the *Missouri Register* on February 15, 2007, for a 30-day review period. The final rule was published by reference in the July 2, 2007, *Missouri Register*, stating that the rule would become effective 30 days after publication. Therefore, this IC is complete.

2) Memorandum of Understanding (MOU) with the Army—DOE will submit a draft updated (or revised) MOU to the Army for review and comment within 6 months of the effective date of this plan.

   Status: DOE met with Army representatives on September 15, 2005, to discuss the updated MOU. DOE delivered a draft of the new MOU to the Army in January 2006, and copied MDNR and EPA. Minor changes were suggested by MDNR and made by DOE. The Army had several changes to the U.S. Army Corps of Engineers project manager position during 2006. Since the new MOU contains both "access" and "restrictive use" provisions, it must be approved by the land owner, the 89th Regional Readiness Command, and the U.S. Army Corps of Engineers as the remedial action controlling agency. Until the new MOU is approved, the existing MOU, together with the existing land use on the Army property, provides a measure of control that is sufficient for current needs to monitor groundwater and prevent groundwater use.

3) Easements—DOE will submit proposed easements to the state agencies within 8 months of the effective date of this LTS&M Plan (DOE 2005a).

   Status: DOE issued initial letters, dated October 12, 2005, to the surrounding State agency property owners in order to reinitiate discussions regarding the proposed easements. DOE, through its realty section and its interagency agreement with the U.S. Army Corps of Engineers (Omaha Office), sent a draft easement and offer letter to MDC in May 2006. The letters were issued to MDNR-Parks and MoDOT in September 2006. DOE received a response from MDNR-Parks dated May 10, 2007. DOE issued additional letters to the three State agencies in August 2007. These letters included copies of the original offer letters and draft easements. The purpose of these letters was to attempt to revitalize the easement negotiations. DOE met with MDNR-Parks on October 22, 2007, and prepared meeting minutes from the meeting and are working towards resolution of issues. DOE issued additional letters to MDC and MoDOT in December 2007, in another attempt to revitalize negotiations. In January 2008, DOE received a response from MoDOT, which stated that MoDOT is working with the other State agencies on the issue.

5.3 Interpretive Center

5.3.1 Interpretive Center Operations

The Weldon Spring Site Interpretive Center is part of DOE's LTS&M activities at the Weldon Spring Site. The purpose of this facility is to inform the public of the Site's history, remedial action activities, and final conditions. The center provides information about the LTS&M program for the Site, provides access to surveillance and maintenance information, and supports community-involvement activities.

Current exhibits in the Interpretive Center present:

- The history of the towns that once occupied this area.
- A timeline of significant events at the Weldon Spring Site (from 1900 to the present).
- The legacy of the Weldon Spring Ordnance Plant and Uranium Feed Material Plant and the manufacturing wastes.
- The events and community efforts to clean up the Site and the people that made it happen.
- The phases of the Weldon Spring Site Remedial Action Project.

These exhibits may be changed as appropriate to changing conditions or emerging issues at and near the Site. The Interpretive Center's hours of operation are posted at the Site. The current hours of operation are:

- Monday through Friday: 9:00 a.m. to 5:00 p.m.
- Saturday: 10:00 a.m. to 4:00 p.m. (10:00 a.m. to 2 p.m. November 1 through March 31)
- Sunday: 12:00 p.m. to 4:00 p.m.

The Interpretive Center is closed on holidays.

Attendance is tracked through the following types of public activities:

- Individuals that walk into the Interpretive Center from the street during normal hours of operation.
- Scheduled groups that participate in Interpretive Center educational programs.
- Community-based organizations that utilize the Paul T. Mydler meeting room to conduct business meetings.
- Scheduled groups who are unable to visit the Site but are recipients of Interpretive Center outreach presentations.

A significant number of individuals also use Site amenities (e.g., Hamburg Trail, disposal cell perimeter road for prairie viewing, disposal cell viewing platform, native plant garden); however, because this use does not involve entering the Interpretive Center and is often outside of normal hours of operation, it is not consistently tracked. It is estimated that between 5,000 and 15,000 individuals per year make use of Site amenities in this way.

Attendance at the Interpretive Center in 2007 was 21,524 (Table 5–1), an increase of nearly 4,800 from 2006. The K–12 educational community continues to have significant interest in Interpretive Center programs. Field trips are usually scheduled several months in advance, and available calendar dates fill up quickly. At times, this requires reservations to be made for the following school year. For a few school districts that have limited funding for field trips, outreach activities are scheduled, and Interpretive Center personnel give educational presentations at the school. Outreach activities usually involve several classes or the entire grade level of students.

Table 5–1. Interpretive Center Attendance

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2002								301	224	190	40	31	786
2003	6	44	44	85	174	191	161	233	251	350	125	122	1,786
2004	52	61	166	182	104	324	192	353	379	850	556	354	3,573
2005	123	605	1056	2048	1888	1408	1370	1091	1511	1663	1739	903	15,405
2006	542	1136	1595	1874	1685	1226	1465	1431	1176	2215	1735	692	16,772
2007	1157	1022	2786	2479	2192	1960	1703	1129	1843	2811	1569	882	21,524
													59,846

Interpretive Center marketing efforts continue to be a critical component of making the public aware of Interpretive Center programs. In 2007, several new educational programs were developed; it was important that teachers be made aware of them so that they could schedule class visits for the 2008 school year.

5.3.2 Howell Prairie and Garden

The 150 acres surrounding the disposal cell have been planted with over 80 species of native prairie grasses and wildflowers. Plants such as prairie blazing star, little bluestem, and wild bergamot will once again dominate this area, which was a large native prairie prior to European settlement. Howell Prairie is one of the largest plantings of its kind in the St. Louis metropolitan area.

A variety of prairie-maintenance activities have been completed throughout 2007. Control of noxious weeds such as *Sericea lespedeza* and *Robinia pseudoacacia* continued. Individual plants were spot-sprayed with herbicide as part of ongoing efforts to keep them from spreading throughout the prairie area. Previous years' control efforts have resulted in significantly fewer numbers of plants, thus limiting the amount of labor needed to complete the activity this season.

In the 2006 annual inspection, erosion areas in the prairie were identified as needing to be monitored and evaluated to ensure that channels were not encroaching into the disposal cell buffer zone. In August 2007, Stoller site-reclamation specialists, representatives from MDNR, and other local prairie experts performed an erosion evaluation. The site prairie establishment history was discussed, and erosion channels were observed. This evaluation showed that erosion was typical for a newly reclaimed site and that vegetation was successfully establishing within the channels, which would allow erosion areas to repair naturally. In response to this evaluation, a Stoller geographic-information-system specialist prepared a detailed map of all erosion areas by walking the site with a global positioning system (GPS) unit. A similar map will be produced in 2008 to track the progress of erosion repair and to ensure that new channels have not developed.

In December 2007, volunteers overseeded in select areas of the prairie, utilizing seeds harvested from the native plant garden.

A garden that consists entirely of plants native to Missouri was designed and planted during 2004. Named the Native Plant Educational Garden, it contains extensive planting of species from Howell Prairie, as well as other perennials, shrubs, and trees. Walking paths, benches, and markers to identify the various plants are located throughout the 8-acre garden. Garden maintenance, consisting of manual weeding, occasional irrigation, and mulching, was performed throughout the growing season. In October and November 2007, dried seed heads from forbs were harvested from the garden to be utilized for hand overseeding on the prairie area of the Site and at other locations throughout the local community. An increasing number of volunteers performed garden-maintenance activities throughout 2007.

The Howell Prairie, the Native Plant Educational Garden, and the Interpretive Center were designed to serve as ICs. These areas will attract visitors to the Weldon Spring Site, help to educate the community about the remediation project, and enhance the Site's educational mission.

5.4 Inspections

The annual LTS&M inspection took place at the Weldon Spring Site from October 24 through 26, 2007. The inspection was conducted in accordance with the *Long-Term Surveillance and Maintenance Plan for the Weldon Spring, Missouri, Site* (DOE 2005a) and the associated inspection checklist. Representatives from EPA and MDNR participated in the inspection. Representatives from the Weldon Spring Citizens Commission and St. Charles County participated in portions of the inspection.

The main areas inspected at the Site were areas where future ICs will be established, the Quarry, the disposal cell, the LCRS, monitoring wells, and assorted general features.

The IC areas were inspected to ensure that pending restrictions, such as excavating soil, groundwater withdrawal, and residential use, were not being violated. Each area was inspected, and no indications of violations of future restrictions were observed.

The disposal cell was inspected by walking 10 transects over the cell and around the cell perimeter at the grade break and the base. Hand-held GPS equipment was used to navigate the 10 transects. Five areas of the cell, which had been marked and located by GPS survey equipment during the 2003 annual inspection, were located and observed for any signs of rock degradation. The LCRS was also inspected and found to be in good condition. Fifty-three of the 119 groundwater monitoring wells were inspected and found to be in good condition. Other Site features including the prairie, site markers, and roads were also inspected. The inspection included contacting stakeholders and IC contacts.

The fourth annual public meeting required by the LTS&M Plan (DOE 2005a) was held in March 2007. The December 2006 inspection, changes to the LTS&M Plan, a summary of environmental data, and the Interpretive Center and prairie were discussed. The fifth annual public meeting to discuss the 2007 inspection was held on April 30, 2008.

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6.0 References

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